DUSKY DOLPHIN NURSERY GROUPS OFF KAIKOURA, NEW ZEALAND

A Thesis

by

JODY SUZANNE WEIR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2007

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee, Bernd Würsig
Committee Members, Jane Packard
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ABSTRACT

Dusky Dolphin Nursery Groups off

Kaikoura, New Zealand. (May 2007)

Jody Suzanne Weir, B.Sc., University of British Columbia

Chair of Advisory Committee: Dr. Bernd Würsig

The distribution, behaviours, and composition of dusky dolphin (*Lagenorhynchus obscurus*) nursery groups off Kaikoura, New Zealand, were examined. Data were collected during January–May 2005 and December 2005–April 2006 by systematic boat based surveys, group focal follows and photo-identification techniques. A total of 99 nursery groups were encountered on survey. Nursery groups were encountered in shallow water (<20 m) significantly more often than in deeper water (>20 m). Other group types (large groups, mating groups, adult non-mating groups) were not found in shallow water significantly more often than in deeper water. By staying in the shallower water, nursery groups may be protected from aggressive conspecifics and predators. More boats, especially private recreational boats, were found in the shallower waters, indicating that nursery groups are at greater risk from encounters with boat motors or recreational fishing gear in such areas. Group focal follows of at least 30-minutes were conducted on 56 nursery groups. Calves engaged in significantly more high energy behaviours (displays and head first re-entries) than non-calves in nursery groups. These groups were predominantly resting and compactly organized (inter-animal distance less than 1 adult body length). Nursery groups showed a high level of synchrony, with 44% of groups synchronizing their submergence and surfacings for most of the focal follow. Median group size was 14, with a minimum of 2 mother-calf pairs to a maximum of 50 mother-calf pairs. A total of 260 individuals were catalogued as members of nursery groups during the two field seasons. Of these, 112 individuals

were seen in nursery groups on at least two different days. Some individuals photographed with young calves in nursery groups off Kaikoura were later photographed in Admiralty Bay, 275 km northwest of Kaikoura. Other individuals photographed together in nursery groups in 2005 were also together in nursery groups in 2006.

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I thank the EarthWatch Institute, the New Zealand Department of Conservation, Marlborough District Council and Texas A&M University for funding provided for this project. Appreciation also goes out to DoC staff Laura Boren and Brian Lloyd, as well as lab buddy Robin Vaughn for the helpful photographs taken in Admiralty Bay while I was in different locations. I also thank Murray Green for keeping our boat running and John Hocking for keeping it floating.

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CHAPTER I

INTRODUCTION

Dusky dolphins (*Lagenorhynchus obscurus*) are a small, robust delphinid with a slightly falcate pointed dorsal fin and little demarcation between the forehead and the jaw (Jefferson et al., 1993). Their distribution is limited to the Southern Hemisphere, where research efforts have focussed primarily on populations off New Zealand (Würsig et al., 1991; Würsig et al., 1997; Barr & Slooten, 1998; Harlin et al., 2003; Markowitz et al., 2004) and South America (Würsig & Würsig, 1980; Würsig et al., 1991; Van Waerebeek & Read, 1994; Crespo et al., 1997; Dans et al., 1997; Coscarella et al., 2003). However, they also occur off South Africa, the Falkland and Tristan da Cunha Islands in the South Atlantic, and the Prince Edward, Amsterdam and St. Paul Islands in the eastern Indian Ocean (Van Waerebeek et al., 1995).

From studies of dusky dolphins killed in fishing operations, we have gained some information on the life history parameters of dusky dolphins off New Zealand and South America. Off New Zealand, dusky dolphins reach lengths of approximately 170 and 180 cm and maximum weights of 85 and 78 kg for males and females, respectively (Cipriano, 1992). This is considerably smaller than the individuals found off Peru, where maximum lengths for males and females are 211 and 204.5 cm respectively. Age at first reproduction for males and females off New Zealand is ~7-8 years (Cipriano, 1992), slightly older than the population off Argentina, where a small sample of females showed sexual maturity at ~6-7 years (Dans et al., 1997). Gestation is estimated to last approximately 11.4 months off New Zealand and 12.9 months off Peru, while lactation has been calculated to last 18 months and 12 months in these two populations, respectively (Cipriano, 1992; Van Waerebeek & Read, 1994). The calving season

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This thesis follows the format and style of *Animal Behaviour.*

coincides with late spring and summer in both areas, while calving off Argentina appears to occur slightly earlier in the year (Würsig & Würsig, 1980). Caution should be taken when comparing these reproductive estimates, however, since the sample sizes were different between studies.

SOCIAL STRUCTURE OF DUSKY DOLPHINS OFF KAIKOURA

Off Kaikoura, on the east coast of New Zealand's South Island (Latitude 42˚25"S, Longitude 173˚41"), up to 2,000 dusky dolphins occur relatively close to shore, within ~10 km. The statistically-calculated population estimate for the area is approximately 12,000 individuals (Markowitz, 2004), but all are never present at one time. In this population, as in most studies of delphinids, we see groups living in "fission-fusion" societies, with individuals changing associations on scales of minutes, days and years. However, through long-term studies, we see subtle patterns of association being clarified for some populations (Whitehead & Weilgart, 2000; Chilvers & Corkeron, 2002; Lusseau et al., 2003; Gero et al., 2005; Karczmarski et al., 2005). Currently, the only quantitative data available for association patterns in dusky dolphins is for small foraging groups in the Marlborough Sounds (Markowitz et al., 2004). The identification of key structural units in a population is the first step towards unravelling details of dolphin societies.

Dusky dolphins off Kaikoura are generally not all grouped in one area. More frequently, one or two large groups of 150 or more individuals, as well as several smaller groups are scattered throughout the greater area. Previous research has identified the specific types of groups that occur in this area (Cipriano, 1992; Würsig et al., 1997; Markowitz, 2004). The structural units considered for the present study include large groups, mating groups, adult non-mating groups and nursery groups. "Large groups" are groups with at least 150 dolphins, often composed of mixed age classes and both sexes. "Mating groups" are smaller groups, composed of fewer than 10 adults, with occasional juvenile members, involved in mating behaviours including intromission, head first re-

entries and chases. "Adult non-mating groups" are small non-sexually active groups of fewer than 10 individuals, composed primarily of adults with occasional juvenile members. "Nursery groups" are groups of mostly mothers and young calves. For the current study, I further defined a nursery group as having at least 2 calves per 6 non calves. A "group" contains all individuals within 10 m of another group member (10 m "chain rule"; Smolker et al. 1992). Occasionally, groups did not fit into any of these categories.

Research efforts off Kaikoura have focused mostly on large groups of dolphins. These are the groups targeted by tour operators in the region and have been the focus of several shore-based studies (Cipriano, 1992; Barr & Slooten, 1998; Brown, 2000; Duprey, 2007), as well as boat-based behavioural studies (Markowitz, 2004). From these studies, it was discovered that large groups swim faster over deep water (Cipriano, 1992), and that they show some short term behavioural changes when in close proximity to tour boats (Barr and Slooten, 1999).

Recently, more thorough studies of the behaviours of smaller groups have been undertaken. Markowitz (2004) found that mating groups, non-mating adult groups, and nursery groups spent less time travelling than did larger groups. He also found that mating groups were comprised of 3 to 35 individuals with most groups having one female and up to 10 males. Some individually distinctive dolphins in a mating group off Kaikoura also fed together ~275 km north, in the Marlborough Sounds (Markowitz, 2004). A total of 39 individuals have been identified as frequenting the Kaikoura area in summer, and the much more shallow and protected Admiralty Bay, in the Marlborough Sounds, in winter (Markowitz, 2004).

We do not know much about nursery groups. The generally inconspicuous behaviours of these nursery group individuals coupled with their frequent separation from the larger groups make them more difficult to locate, approach and follow. Yin (1999) tracked the movements of small groups (<25) with and without calves from a shore based theodolite station and found that the mean leg speed for groups with calves (4.21 km/h) was not statistically different than that of small groups without calves (4.75

km/h). Calf groups also displayed more linear travel than groups without calves (Yin, 1999). Markowitz (2004) found that nursery groups exhibited generally tight inter-individual proximity and parallel swimming formation. There are many aspects of nursery groups which remain undetermined. For example, nursery groups may prefer shallower water than do other group types (Würsig et al., 1997); yet, no dedicated effort has been made to verify this assumption.

Aspects of distribution, social structure, and behaviour change by species and habitat. For example, Gowans and Whitehead (1995) found that different species of odontocetes demonstrate habitat partitioning around a deep submarine canyon on the east coast of Canada. The habitat partitioning and distribution of sperm whales, *Physeter macrocephalus*, (Whitehead & Weilgart, 2000), humpback whales, *Megaptera novaeangliae*, (Ersts & Rosenbaum, 2003) and grey whales, *Eschrichtius robustus* (Swartz, 1986) have all been found to reflect social organization during at least part of the year. A detailed study of nursery groups is required for more complete knowledge of use of dusky dolphin habitat off Kaikoura.

THE SOCIALITY OF MOTHERS AND CALVES

Reproductive and calf-rearing parameters for dusky dolphins have largely been estimated by samples of dead animals caught incidentally in fishing operations, and thus we still know little about the behavioural ecology of dusky dolphin mothers and calves. Longitudinal studies of bottlenose dolphins (*Tursiops truncatus*) in other areas provide information on the social behaviour of some individual mother-calf pairs of delphinids. Two of the best long term data sets come from Shark Bay off Western Australia, and Sarasota Bay off western Florida. In both of these populations, mothers spend a large percentage of their time alone with their calves (Connor et al., 2000), with no other dolphins in the area. When they do associate with other individuals, it is usually in very small groups of 3-7 (Connor et al., 2000). The association patterns, as measured by coefficients of association (100=always sighted together to 0=never sighted together), range from near 100 for mothers and their calves during the first few years, to 30 for

mature females in Sarasota Bay to less than 20 for some females, who seem to have adopted solitary strategies hypothesized to be linked to foraging tactics (Connor et al., 2000). To date, no study has been undertaken to calculate the levels of association for individuals in dusky dolphin nursery groups.

KAIKOURA AS A FIELD SITE FOR A NURSERY GROUP STUDY

The population of dusky dolphins off Kaikoura has been studied since the 1980's (Würsig et al. in press). Unlike the relatively sheltered environments offered by the Shark Bay and Sarasota Bay study areas, the Pacific coast of New Zealand's South Island is exposed to frequent severe storms with winds reaching over 100 km/hr and swells over 5 meters. These storms, coupled with the high level of primary productivity in the area, lead to relatively low in-water visibility. Unlike the Shark Bay field site, where the subtle behaviours of mothers and calves can be observed in great detail to several meters below the surface, off Kaikoura we are limited to mostly surface observations with behaviours such as nursing infrequently observed due to poor water clarity.

In addition to the environmental conditions of the field site, the dusky dolphin population off Kaikoura is difficult to study for at least 6 other reasons: 1) since the number of dolphins present in the area on any given day is quite high, with up to about 2,000 dusky dolphins at times, the likelihood of recording all individuals present every day is nearly impossible; 2) dusky dolphins that are in the study area one day, might travel great distances between sightings off Kaikoura (Würsig et al., 1991), and thus the partial exchange of individuals in the study area on the scale of days to seasons is not easy to estimate based on standard photo-identification techniques; 3) the number of individuals that can be identified based on individual markings is low, with mark-rate estimates of about 50% (Markowitz, 2004), with the remainder of the individuals in the population being indistinguishable by present methods; 4) few calves have markings that can be used for identification purposes; 5) there is no strong sexual dimorphism in this population (Cipriano, 1992), and it is therefore difficult to sex individuals under

most observation conditions; and 6) mothers with calves often avoid boats more often or more rapidly than non-mothers, making it difficult to follow a pair within a group of hundreds of individuals. These factors combine to make study questions and methods for dusky dolphin nursery groups different from studies of bottlenose of Shark Bay or Sarasota.

RESEARCH POSSIBILITIES

Despite the limitations imposed, there are types of research that can be pursued relative to mothers and calves off Kaikoura by use of dedicated and efficient study methodologies. Systematic survey routes of the area can be created and followed to fairly examine the distribution of nursery groups compared to that of other group types. These surveys can also be used to quantify relative boat and predator levels in different parts of the study area. Finally, the positions of these can be compared spatially with categories of depth and other aspects of the environment, to better describe habitat selection of nursery groups.

By conducting group focal follows (Whitehead, 2004), data can be collected on the behaviours of nursery groups. Correlations can be revealed between behaviours of nursery groups and time of day or season. Photo-identification methods can be employed to: 1) record association patterns between marked individual mothers; 2) estimate the number of females raising calves in the area; and 3) estimate seasonal patterns of individual site fidelity for reproductive females.

RESEARCH QUESTIONS

By conducting research dedicated to the distribution and behaviours of nursery groups off Kaikoura, I filled a major gap in our understanding of dusky dolphin societies. I compared the distribution and behaviours of nursery groups to other structural units of the population, and compared my findings with other studies of cetacean social structure and habitat use. My general research questions were these: 1)

Do nursery groups prefer shallow water? 2) What factors predict group distribution? 3) What are the behaviours and association patterns of nursery groups?

IMPORTANCE OF RESEARCH

In addition to contributing to our general knowledge of dusky dolphin societies, the present research is beneficial to local conservation and management efforts. By better interpreting the distribution and hence the habitat choices of females with young calves, I have obtained a better understanding of the needs of reproductive females. By revealing the behaviours of nursery groups, I highlighted key differences between the dolphin group types off Kaikoura and reflected upon management considerations for the entire population, as well as those that might be required for these specialized subgroups.

CHAPTER II

RELATIVE DISTRIBUTION OF DUSKY DOLPHIN SUBGROUPS: ARE SHALLOW WATERS A REFUGE FOR NURSERY GROUPS?

INTRODUCTION

Understanding both where and why mothers and their young calves seek refuge can aid managers in designating localized areas as especially important to the species. Young individuals are especially vulnerable to harm due to their smaller size, less developed skills, and dependence on maternal care. Off Kaikoura, New Zealand, dusky dolphin mother-calf pairs are often found in small groups with other mother-calf pairs, with the calves of roughly the same age. These groups, termed "nursery groups," may distance vulnerable calves from more active and potentially agonistic males as well as from predators in deeper waters. It is also possible that nursery groups form in response to boating activity associated with larger dolphin groups in the area. In this study, I examined the distribution of nursery groups and specifically examined 3 possible explanations for why nursery groups, defined as groups of predominantly mothers and their young calves, may be seeking refuge in this area.

A complex interplay of environmental and biological factors helps to determine a population's or subgroup's distribution, social strategies, and behaviours. Rather than a predictable pattern across species, we see instead species and habitat specific explanations for grouping patterns (Gygax, 2002). In populations where the females have postpartum oestrus, females with young calves may be harassed by males seeking mating opportunities (Connor 2000). Females and young calves grouping together to gain protection from males is suggested for a number of species including chimpanzees, *Pan troglodytes*, (Wrangham 1980); southern sea lions, *Otaria byronia*, (Campagna et al. 1992), and lions, *Panthera leo*, (Packer et al. 1990).

Females with young may also be seeking refuge from predators. Studies of cetacean societies indicate that predation pressure can be a significant factor in group

formation and distribution (e.g. sperm whales) Whitehead & Weilgart, 2000, and bottlenose dolphins, Mann & Barnett, 1999, as has been shown for other groups of animals (Lima & Dill, 1990). The effectiveness of vigilant behaviour by mothers may be greater when in smaller groups compared to large groups. In a study of schooling shiners, *Notropis heterodon*, group formation differed based on the presence or absence of a predator (Abrahams & Colgan, 1985). In this case, increased vigilance was achieved at the cost of decreased hydrodynamic efficiency.

Wild dolphins may respond to human disturbance in the same way they do when faced with a potential predator (Bejder et al., 1999). There is a considerable amount of recreational and tour boat traffic in the study area (Duprey, 2006) and nursery groups may be forming due to comparatively greater perceived risk. The less refined motor skills of calves, coupled with the high energetic requirements of a lactating female, may lead to segregation into nursery groups when presented with human disturbance. It has been demonstrated that behavioural responses to boat disturbance are dependent on sex and reproductive status of bottlenose dolphins in Doubtful Sound, New Zealand (Lusseau, 2003) and killer whales off British Columbia, Canada (Williams et al., 2002).

Off Kaikoura, hundreds of dusky dolphins (*Lagenorhynchus obscurus*) rest and socialize near shore during the day and feed on the rising deep scattering layer of myctophids and squid at night (Würsig et al. 1997). On most days, the area will be host to one or two large groups of dusky dolphins (150 -1000 individuals) as well as several smaller sub-groups. One common type of sub-group seen in the area is termed the "nursery group." For this study, a nursery group is defined as a group with 1 calf per 3 or fewer non-calves. Calves are defined as individuals younger than 1 year based on smaller body size (< 1.2 m), less distinct colouration pattern, cork-like surfacings and consistent echelon position with an adult. I observed the distribution and behaviours of nursery groups off Kaikoura and examined whether these could be predicted by the distribution and abundance of males, boat traffic and/or predators. I tested 3 potential hypotheses: the "male hypothesis" suggests that nursery groups form and seek refuge to evade aggressive male conspecifics: the "boat hypothesis" implies that nursery groups

form and seek refuge to reduce interactions with boats; and finally, the "predation hypothesis" states that nursery groups are seeking refuge from predators. I recognize that all, two of these, none of these, or other factors could be operating.

Male hypothesis

Most calves off Kaikoura are born between November and January after an estimated gestation length of 11.4 months (Cipriano 1992). Newborn calves measure between 97 and 120 cm, compared to the adult length of 165 to over 186 cm. Lactation is estimated to last 19 months (Leatherwood & Reeves, 1983). Most mating behaviours take place in the summer months of December–February (Markowitz 2004). This is also the time of year when largest male testes of over 1 kg have been recorded, compared to other times of the year (Cipriano 1992). These observations have been suggested as evidence of a restricted breeding season. Mating behaviours are usually observed within large groups or in smaller "mating groups." These groups are generally composed of fewer than 10 adults, involving mostly males and 1 or more female, with behaviours including head-first re-entries and chases. It is possible but mere speculation at this point, that a strategy of males separating one or more females from a group is taking place. If so, there may be some similarity to the better-described case of "male coalitions" of bottlenose dolphins of Shark Bay, Australia (Connor et al., 1996). If females with young calves are forming nursery groups to evade harassment by males, I would expect to find more nursery groups during the summer months when male oestrous is likely to be peaking. Here, we assume that females with young calves are not in oestrous and therefore probably not interested in sexual or agonistic interactions with conspecifcs that may include high energy behaviours, potential separations of mother and calf, and/or injury to the calf. I would also expect to find fewer mating groups in the areas most frequented by nursery groups.

Boat hypothesis

The human population of the district of Kaikoura is roughly 2,500, with over 500,000 tourists visiting the town of Kaikoura each year (Simon and Fairweather 1998). Boat traffic is primarily small, private recreational boats that are fishing in the area. Commercial tour boats are considerably larger in size than the private recreational vessels but make up a smaller percentage of boats. Current commercial tourism includes a maximum of 112 whale-watching and 50 swim-with-dolphin trips each week, with other sporadic tours to see seabirds, scuba dive, and swim with seals. The number of commercial fishing vessels in the area varies among days and seasons, but on most days 1 or 2 will be present in the study area. If nursery groups are forming to separate themselves from boat traffic, I would expect to find more nursery groups at times of the year when we see the most boat traffic. I would also expect to see less boat traffic in areas most frequented by nursery groups.

Predator hypothesis

Finally, the predator hypothesis proposes that predation pressure is the most important factor in influencing nursery group distribution. The two main predators of dusky dolphins off Kaikoura are killer whales (*Orcinus orca*) and sharks. Sightings of killer whales in New Zealand are monitored by researchers as well as commercial recreational tour operators. From 1978-2005, there have been more than double the number of killer whales sighted off Kaikoura in December and January than in any other two-month month period (Ingrid Visser, personal communication). Killer whales have been witnessed killing and feeding on dusky dolphins in the area (Constantine et al. 1998). More common than seeing kills, are sightings of dusky dolphins pressing up close to shore and even beaching themselves when killer whales are in the area (Würsig et al. 1997, Constantine et al. 1998).

Sharks have been little studied in the area. Fishermen and tour operators report that from the surface, blue sharks (*Prionace glauca*) are the most common shark seen in the area, followed by mako sharks (*Isurus oxyrinchus)* and thresher sharks (*Alopias*

vulpinus) which are spotted infrequently (Ian Bradshaw, personal communication). All three of these shark species are usually sighted between December and January. One fisherman reported catching 30-40 bins of cookie cutter sharks (*Isistius brasiliensis*) per day in waters over 200 m deep, although these sharks are never seen at the surface (Peter Bradshaw and Ian Bradshaw, personal communication). While no one has documented a case of a shark attack on a dusky dolphin, some of the dolphins bear scars from shark bites ranging in size from 15 to 30 cm across (personal observation). If the predation hypothesis is correct, I would expect that nursery groups are found more often during summer months, when predation risk is likely to be highest. I would also expect nursery group distribution to differ from that of predators in the area. I investigated the relative distribution of nursery groups to see in what depths they were found, compared to other dolphin sub-groups, predators, and boats. I then considered which of my three potential factors might best predict formation and distribution of the nursery groups off Kaikoura.

METHODS

Study area

The town of Kaikoura is located on the east coast of New Zealand's South Island (42.30˚ S/173.32˚ E). Between the Kaikoura Peninsula and Haumuri Bluffs (Fig.1), there is an open-ocean embayment, approximately 100 km^2 in area. The area is largely characterized by the Upper Kaikoura Canyon, a deep underwater canyon that extends to within 200 m of shore at Goose Bay (Lewis & Barnes, 1999) and reaches depths of over 1400 m. The bathymetry of the continental shelf consists largely of fine sand, mud and some smaller patches of pebble and boulder gravel (Lewis & Barnes, 1999). Two rivers, the Kahutara and the Kowhai River, empty into the area and there is a third river, the Conway River, that empties just south of the study area but nonetheless spills into the area around Haumuri Bluffs.

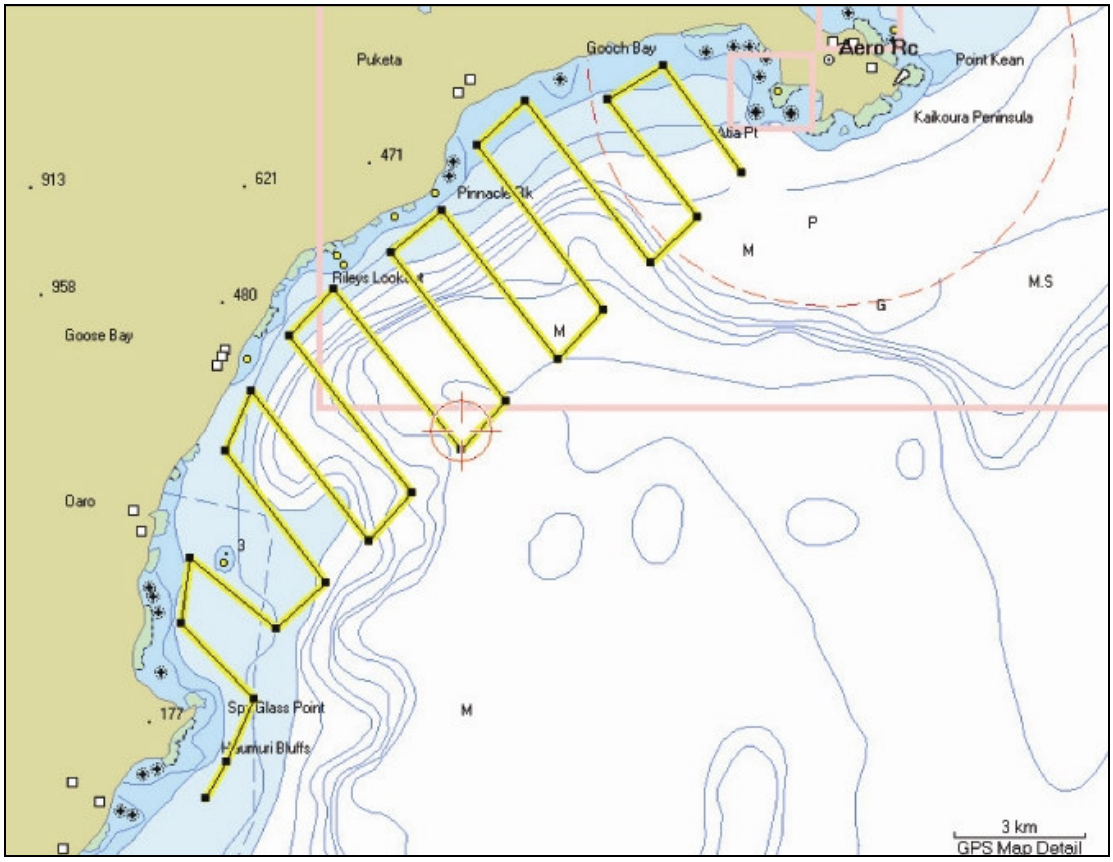

Figure 1. Map showing survey route for nursery group study.

Survey methods

A survey route (Fig. 1) was programmed into a Garmin GPS and followed at a speed of approximately 20 km/h. The start point on the route alternated among three locations (either end and the middle). The boat was 5.5 m long and powered by an 85 Hp 2 stroke engine until December 2005, when it was changed to an 80 Hp 4 stroke engine. Each survey day, I started at the pre-determined location and followed the survey route until a dolphin group was sighted. The survey route was 66.2 km long and took approximately 3.3 hours to complete (if there were no stops made or groups encountered), driving at speeds of approximately 20 km/h.

Using descriptions set forth by previous researchers (Markowitz, 2004), each dolphin group encountered was classified as being one of nursery group, mating group,

non-mating adult group or large group (Table 1). The GPS location was recorded and group composition was determined by counting the number of individuals in the group. For larger groups, group size was estimated by counting the number of individuals at the surface at any one time. Each individual within 10 m of any other group member was considered part of the group (10 m "chain rule"; Smolker et al. 1992). During surveys in 2006, I also recorded the positions of killer whales, sharks, and boats. Boats were classified as one of the following groups: private recreational, commercial tour, or commercial fishing boats.

Behavioural descriptions

To supplement distribution data, I collected behavioural information associated with predator presence, probable male harassment, and boats while conducting focal follows of nursery groups (explained in detail in Chapter III). The descriptions used to assign each of these terms are outlined in Table 2.

Table 1. Terms used and descriptions of dolphin group types encountered during 2005-2006 nursery group study.

Term Used	***Description***
Nursery Group	A group with at least 2 calves per 6 non calves
Mating Group	A small group of less than 10 adults, with occasional juvenile members, involved in mating behaviours including head first re-entries and chases
Adult Non-Mating Group	A small non-sexually active group composed primarily of adults with occasional juvenile members
Large Group	A group with at least 150 dolphins, often consisting of mixed age classes
Adult	Dolphin over 1.5 m in length
Juvenile	Dolphin estimated to be over 1 year old based on larger body size (>1.2 m, less than 1.5 m), no "cork-like" surfacings and no consistent echelon position with an adult
Calf	Dolphin estimated to be less than 1 year old based on small body size (=/< 1.2 m) and poorly defined coloration pattern, "cork-like" surfacings, and consistent echelon position with an adult

Table 2. Descriptions of rare events documented during focal follows of nursery groups.

Term used	***Description***
Harassment by males	Sudden fast/burst swim by nursery group members accompanying the arrival of new adult dolphins. Chasing of group members by new adult dolphins and possibly attempts to separate members by aggressively moving in between mothers and calves. Sex of dolphin presumed as male by seeing the penis or by repeated approaches towards a female from below in attempts at intromission.
Boat encounter	Boat of any kind other than the research boat arriving within 300 m of the nursery group.
Predators in the area	Personal sighting of a shark or killer whale while conducting a focal follow of a nursery group, or a confirmed sighting in the area reported over the marine radio by local tour operators.

Analysis

I used MapSource BlueChart Pacific v5.5 software to plot each encounter with a dolphin group on digital maps of the area, and determined the category of depth for each GPS location. For most analyses, depth category was either <20 m ("shallow") or >20 m ("deep"). To test whether groups were found significantly more often in shallow waters, I corrected for the amount of time spent "searching" in shallow versus deep water and performed Chi-square analyses of potential differences. To illustrate the seasonality questions, I plotted encounter rates per hour by two-week time blocks. For samples with low sample sizes, I used descriptive measures to best explain rare occurrences of boat encounters, harassment by presumed males, and predator presence in the area.

Every dusky dolphin group encountered on survey in 2006 was categorized and coded with respect to: 1) depth (<20 m *or* >20 m); 2) season (summer or fall); 3) level of boat presence (no other boats within ~500m of the group *or* 1 or more other boat(s) within ~500m of the group); 4) harassment potential for females (1:1 adults and calves *or* 1+:1 adults to calves *or* all adult non-mating groups *or* visible harassment of a female) and 5) predator presence (none *or* within 3 days *or* on that day). My scale of harassment potential assumes that females with new calves are not in oestrous and therefore not interested in potentially sexual agonistic interactions with males. Therefore, the least likelihood of harassment would occur in a nursery group with only

mother-calf pairs and no extra individuals (i.e. 1:1 adults and calves). With the aid of SPSS 13.0, I performed a logit regression, using the variables of boat presence, harassment potential for females and season to predict the depth category (>20 m or <20m) where dolphin groups were encountered. For this particular analysis, depth was the dependent variable and boat presence, harassment potential, predator presence, and season were the independent variables.

RESULTS

Survey effort

A total of 77 days (44 in 2005 and 33 in 2006) and 186.4 hours (124.1 hours in 2005 and 62.8 hours in 2006) were spent surveying the waters between the Kaikoura Peninsula and Haumuri Bluffs. Details of the survey route and survey effort results are outlined in Table 3.

Table 3. Survey effort and nursery group encounter rates for 2005 and 2006

Variable	Under 20 m	Over 20 m	Total
Survey route length	21.9 km	44.4 km	66.2 km
Survey effort 2005	788.2 km	1693.8 km	2482.0 km
Survey effort 2006	418.5 km	826.5 km	1245.0 km
Survey route hours	1.1 hr	2.2 hr	3.3 hr
Survey hours 2005	39.4 hr	84.7 hr	124.1 hr
Survey hours 2006	20.9 hr	41.3 hr	62.3 hr
Number of nursery groups encountered per kilometre	0.06/km (n=77)	0.01/km (n=22)	0.02/km (n=99)
Number of nursery groups encountered per hour	1.28/hr (n=77)	0.18/hr (n=22)	0.53/hr (n=99)

Dolphin groups encountered

During surveys in 2005, I encountered 71 nursery groups and 48 large groups. Neither mating groups nor adult non-mating groups were recorded in 2005. During surveys in 2006, I encountered 28 nursery groups, 18 mating groups, 85 adult non-mating groups, and 28 large groups. Thus, in 2006, nursery groups made up 17.6% of dusky dolphin groups encountered on survey. The initial encounter locations of all 71 nursery groups are shown in Figure 2.

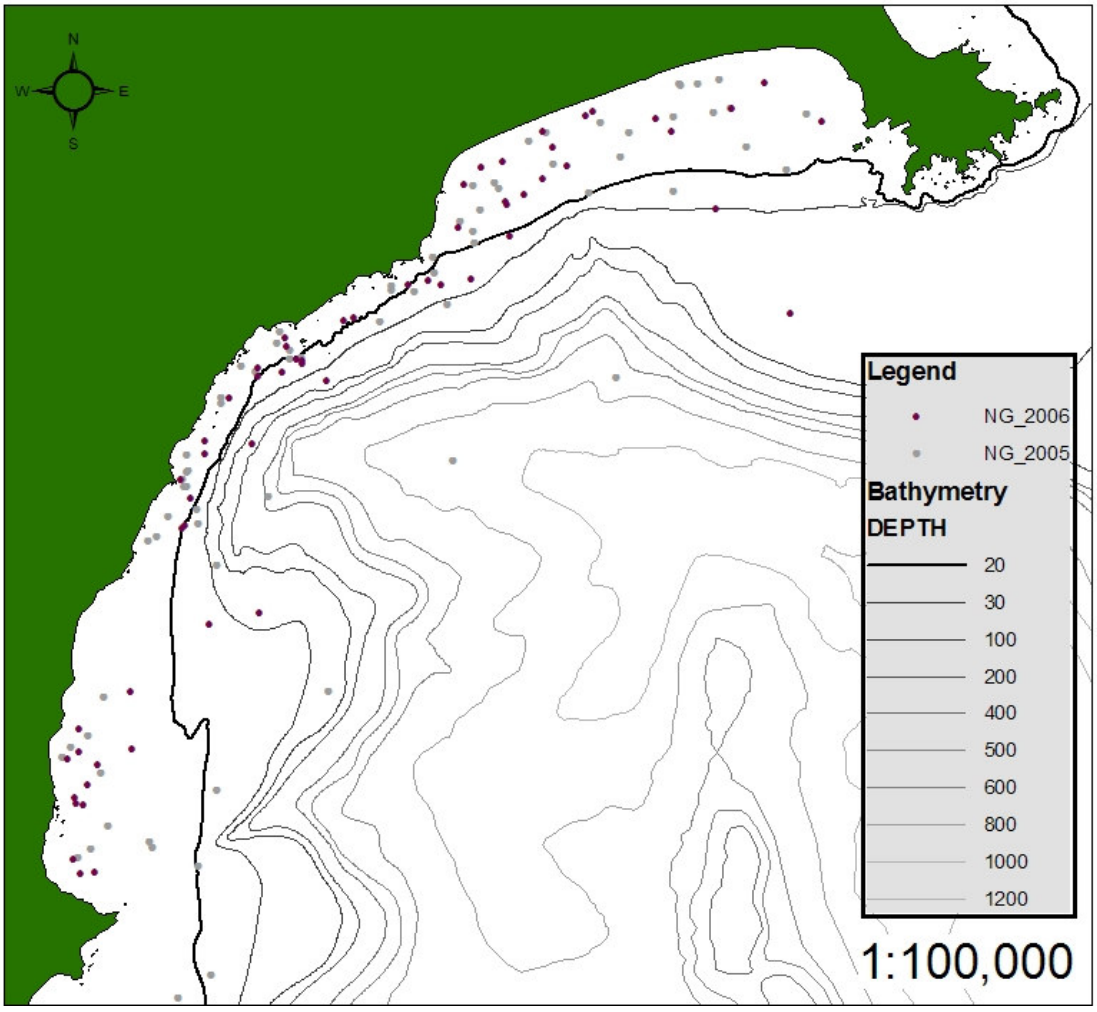

Figure 2. Initial locations of all nursery groups (N=71) encountered on survey during 2005 and 2006.

Relative distribution of group types

The area covered by the survey route was just under 100 km^2 (approximately 97.5 km^2). Of this area, only 34% (33.6 km^2) was in depths under 20 meters. Combining data from both 2005 and 2006, and accounting for difference in area less than and over 20m depth, nursery groups were encountered in shallow waters (<20 m) significantly more often than deeper waters (Chi-Square (df=1, N=99) =89.778, p <0.001). Using survey data from 2006, different group types (i.e., nursery groups, mating groups, adult groups, and large groups) were not found in shallow waters with equal frequency (Chi-Square (df =3, N=159) =11.138, p =0.011, Table 4).

Table 4. Dusky dolphin group types encountered per hour of search effort

Variable	Year	Under 20 m	Over 20 m	Total
Nursery groups	2005	1.42 (n=56)	0.18 (n=15)	0.57 (n=71)
Nursery groups	2006	1.00 (n=21)	0.17 (n=7)	0.45 (n=28)
Mating groups	2006	0.38 (n=8)	0.24 (n=10)	0.29 (n=18)
Adult Non-Mating groups	2006	1.58 (n=33)	2.06 (n=52)	1.37 (n=85)
Large groups	2006	0.62 (n=13)	0.36 (n=15)	0.45 (n=28)

Shallows as a refuge from males

Although nursery groups were found significantly more often in shallow waters than deep water, this was not the case for other group types. When adult non-mating and mating groups were combined for 2006, and accounting for the difference in area less than and over 20m depth, there was no significant difference (Chi-Square (df =1, N=103) =2.158, p =0.142, Table 4) in the number of groups found in deep and shallow waters. There was also no significant difference (Chi-Square (df=1, N=18) =2.620, p=0.106, Table 4) between the number of large groups encountered in deep and shallow waters.

If nursery groups are forming to evade harassment by males, I expected to find more nursery groups during the summer months of January and February when the males are in oestrous and the females with new calves are likely not. In Figure 3, encounters per hour of survey effort are shown by 2-week time periods throughout the 2006 field season. Approximately 10 times more mating groups and adult groups were encountered than nursery groups during the first time period from January 8–21. During the next time period, the situation is reversed and we encountered 20 times more nursery groups than mating groups and adult groups. During the next time period, from February 5–18, we had a peak in adult groups, an increase in mating groups, and a decrease in the number of nursery groups. Since the difference between an 'adult non-mating group' and a 'mating group' is primarily a behavioural difference, the trend we see in mid-February may be interpreted as a shift away from mating behaviours during that time of the year coinciding with a probable decrease in male oestrous. Alternatively, since this is a significant peak in "adult groups," this may actually indicate an increase in mating groups at this time, and I did not happen to observe these groups mating during our encounters with them. At this point in the season, the number of nursery groups dropped significantly from earlier in the summer. From the seasonal data, it is difficult to discern a positive or negative correlation between nursery groups and mating groups; however, there were more nursery groups forming in January and February than other times of year.

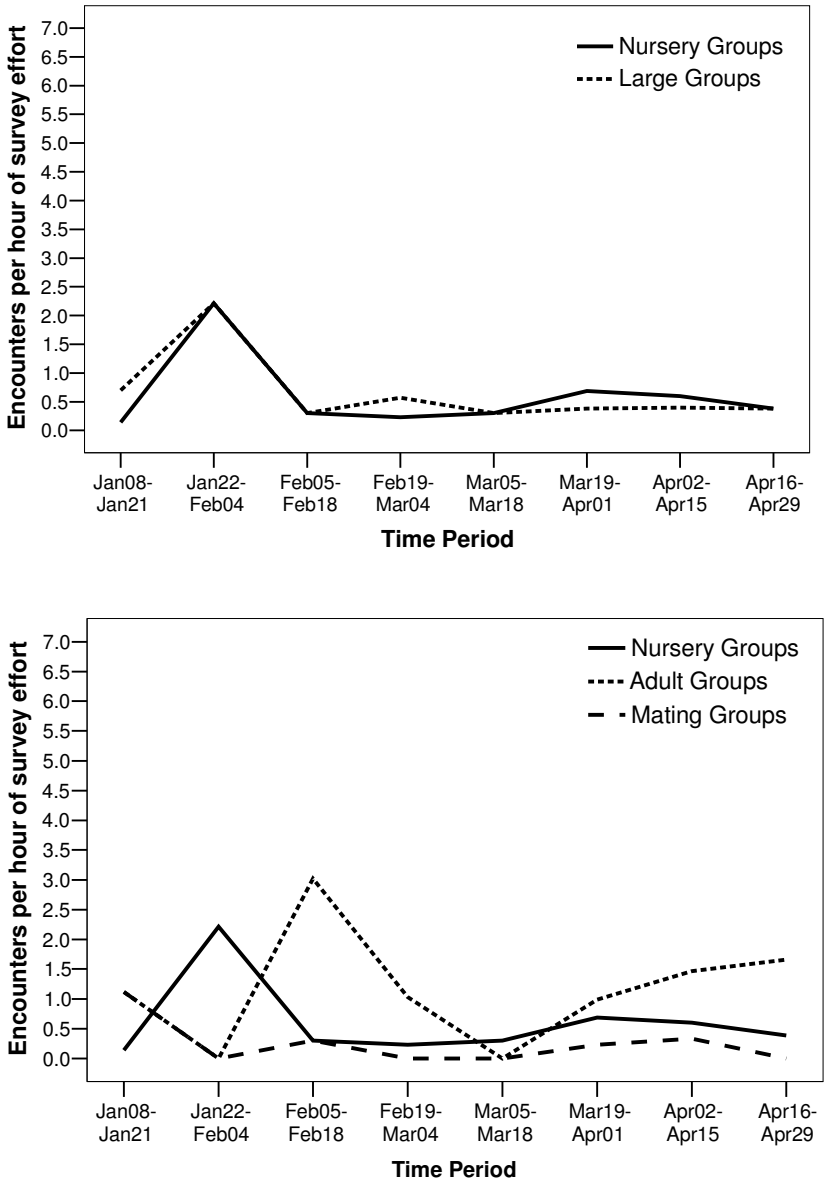

Figure 3. Encounters with dolphin groups by hour of survey effort divided into 2-week time periods. All dates correspond to the 2006 field season.

During a total of 56 focal follows of nursery groups over both seasons, obvious harassment by males was only observed 5 times. For 2 of these instances, the depth where the harassment took place was recorded. One was in shallow and the other in

slightly deeper water. Overall, mating groups did not appear to have a preference for shallow or deeper waters, nor were nursery groups being frequently harassed.

In one extreme example of harassment, 8 large adults arrived when I was following a nursery group of 8 adults and 8 calves. Immediately coinciding with the initial arrival of the outside individuals, there were aggressive chases of the entire nursery group and the apparent males continually surged their bodies between mothers and calves in what appeared to be attempts to break-up the group. Calves often appeared to be struggling, with laboured breathing and random disoriented movements when not in echelon with an adult. This event took place on January 8, 2006, when the calves were still quite young. The water in the localized area was churned and wavy even though it was a very calm day (and other areas of water were not as rough). Females were attempting to evade the probable males by rolling on their sides and often rising vertically out of the water. Mating was observed on at least 10 occasions (Fig. 4). On at least 4 occasions, a female and calf pair broke-off from the group on its own, only to slowly return to the group. The females seemed intent on staying with their nursery group. I witnessed this continual very-high energy behaviour for over 90 minutes.

a.)

b.)

c.)

d.)

Figure 4. Harassment of a nursery group by males. a) Water being churned as males surge their bodies between mothers and calves b) a calf disorientated while separated from mother c) male mating with a female who has a young calf d) female rolling on her side to avoid male.

In another example of apparent harassment, the probable males seemed to employ an alternative strategy. I was conducting a focal follow on a group with 5 adults and 4 calves. For the first 10 minutes of the follow, the group was resting until a group of 5 probable males arrived; the group began fast swimming and a mother and calf became separated from the group. Instead of all the males chasing the entire nursery group, the probable males separated one female and her calf from the group, and spent over 20 minutes chasing her as a group, from either side and from below. The female was unable to flee the males for more than a few meters before the group of males would stop her. The female frequently rolled on her side and occasionally onto her back to avoid the males but often she seemed to be struggling to get her head out of the water to

breathe. During this encounter, the rest of the nursery group had fled towards the shoreline and the female's calf stayed close (within 7-10 m) but on the outside of the tightly packed mating group consisting of its probable mother and 5 probable males.

Shallows as a refuge from boats

The number of private recreational boats encountered per hour of search effort was higher in depths under 20 m, yet commercial fishing boats were encountered more often in water deeper than 20 m (Table 5). When all boat types were combined, there were significantly more encounters in shallow waters (Chi-Square (df=1, N=258) =6.478, p=0.011, Table 5).

Table 5. Boat types encountered per hour of search effort during 2006

Variable	Under 20 m	Over 20 m	Total
Nursery groups	1.0 (n=21)	0.2 (n=7)	0.5 (n=28)
Private Recreational	2.3 (n=49)	1.2 (n=48)	1.6 (n=97)
Commercial Tour	2.5 (n=52)	2.1 (n=86)	2.2 (n=138)
Commercial fishing boats	0.1 (n=3)	0.5 (n=20)	0.4 (n=23)
All boats	5.0 (n=104)	3.7 (n=154)	4.2 (n=258)

During 56 focal follows of nursery groups over both seasons, encounters with boats other than the research boat (boats coming to within 300 m of the nursery group) occurred 14 times. For 7 of these instances, depth where the boat came within 300 m of the group was recorded. Six instances were in shallow waters and only one instance was in deeper waters. In all but one of these cases, the boat was travelling by and did not slow down to view the nursery group. In another case, a small recreational boat came straight towards the research boat, for the occupants to ask us a question, and they did not even notice the dolphins until I told them of their presence. In general, the inconspicuous behaviours of the nursery groups made them difficult for boaters to see.

When boats approached closely, to within approximately 300 m, nursery groups responded by travelling away in the opposite direction. On 3 occasions when boats travelled very quickly through an area with a nursery group, the group dove and did not surface for over a minute, considerably longer than a normal dive. When they surfaced again, it was in a location 50–100 m from where they had first submerged. On 2 occasions, nursery groups were within 200 m of commercial trawlers that were actively trawling the bottom near the mouth of the Kahutara River.

Shallows as a refuge from predators

During the 2006 field season, I encountered 9 groups of killer whales and 8 individual blue sharks. Both sharks and killer whales were encountered almost exclusively in deeper waters. Compared with nursery group encounters, killer whales and blue sharks were seen much less in depths under 20m but had similar encounter rates in water over 20 m (Table 6).

Table 6. Potential predators encountered per hour of search effort during 2006

Variable	Under 20 m	Over 20 m	Total
Nursery groups	1.00 (n=21)	0.17 (n=7)	0.45 (n=28)
Killer whale groups	0.05 (n=1)	0.19 (n=8)	0.15 (n=9)
Shark *spp*.	0.00 (n=0)	0.19 (n=8)	0.13 (n=8)

Most killer whale groups were recorded in the warmer summer months and in deeper waters (Table 7). All of the blue sharks were recorded during April, in deep waters, and all but one were basking at the surface (Table 8).

Table 7. Killer whale sightings 2006

Date and Time	Number of Killer Whales	Depth	Shallow or deep?	Behaviour
Dec 21, 9:33	3	200-300m	Deep	Possible feeding on fish at depth
Jan 07, 16:21	4 (12 total in area)	20-30m	Deep	Travel South
Jan 11, 6:28	2	20-30m	Deep	Travel North
Jan 11, 7:17	7	10-20m	Shallow	Travel North
Jan 11, 10:23	6	30-50m	Deep	Travel North
Feb 13, 17:11	18	50-100m	Deep	Travel South
Feb 26, 11:40	3	30-50m	Deep	Travel North
Mar 07, 8:46	3	30-50m	Deep	Travel North
Apr 19, 12:38	20	20-30m	Deep	Travel North

Table 8. Shark sightings 2006

Date and Time	Depth	Shallow or deep?	Behaviour
Apr 01, 9:02	500-1000m	Deep	Basking
Apr 01, 12:38	101-500m	Deep	Basking
Apr 05, 10:23	101-500m	Deep	Basking
Apr 06, 11:11	101-500m	Deep	Basking
Apr 07, 14:43	500-1000m	Deep	Basking
Apr 08, 9:12	31-100m	Deep	Basking
Apr 08, 11:49	31-100m	Deep	Basking
Apr 14, 11:03	31-100m	Deep	Feeding on dead dogfish

Over the two field seasons, I did not witness an attack by a shark or killer whale on a nursery group. On most days, I was unable to find nursery groups when killer whales were sighted in the area. However, on April 19, 2006, I was conducting a focal follow, when killer whales were reported in the area. The nursery group had been foraging in pack formation in an area very close to South Bay ramp, within 200 m of the shoreline. At 28 minutes into the focal follow, another small group of dolphins came travelling very rapidly towards the nursery group that we had been following. When they arrived within approximately 10 meters of the nursery group, the nursery group

suddenly began burst swimming as a group in parallel formation towards the shoreline. Within 5 seconds of this occurring, a tour boat operator radioed that a group of 20 killer whales had just been sighted in the area. After this, I was unable to approach within 50 m of any dolphin group for the rest of the day. Generally, nursery groups were difficult to find on days when killer whales were present, and were difficult to approach when found.

One particular incidence of presumed stress due to killer whales occurred on February 26, 2006. I had returned to South Bay ramp at the end of a field day to find a solitary dusky dolphin calf (later measured at 119 cm length) swimming within the South Bay harbour. Killer whales had been recorded in the area earlier that day and locals reported first seeing a calf close to shore within 1 hour of the killer whales having left the greater area. By 15:00, the dolphin had been within the shallow harbour for 3–4 hours. I recorded the dolphin's breathing patterns and other behaviours until losing daylight at 21:04. During this time, the dolphin frequently came within meters of the shoreline, often coming within 1 meter of people standing in the water. The calf frequently vocalized loudly enough for people to hear it above water. I also recorded the calf chasing small fish in the shallows. On 3 occasions the calf engaged in a head first re-entry leap in slightly deeper waters. Occasionally, it came close to the exit of the harbour although it did not leave during daylight hours. The following morning, at 07:30, the dolphin was approximately 100 m to the west along the shoreline, in a very shallow (< 1 m) tide pool. It was still alone and now had numerous scratches and marks on its body, especially the end of the rostrum where it was bleeding. Since the dolphin's condition appeared to be deteriorating, the decision was made by the local branch of the New Zealand Department of Conservation to capture it and transport it by boat to the large group of dolphins that was approximately 20 km south of the boat ramp that day. The dolphin was quick to rejoin the other dolphins and appeared strong as it swam away with an adult within seconds of being released. This particular incident was an interesting opportunity to study the behaviours of a dusky dolphin calf under presumed stress from killer whales. The dolphin did not leave the area near shore to search out its'

group. It is possible that it was separated from its group and mother during the fast swim towards shore or that it became lost or disorientated during the rush towards shore. It is also possible that the dolphins' mother was injured or killed by the killer whales.

Predictors of dolphin group distribution by depth

Season, presumed harassment potential, and whether other boats were or were not present, were used to predict the water depth category of each dolphin group. Predator presence was not included due to small sample sizes. Harassment levels and the presence of boats were both significant predictors of the depth category in which a group was found ($p<0.03$). Season did not have a significant effect ($p>0.05$). Boat presence increased the odds of a group being in greater than 20 m water depth by a factor of 3.41. As harassment potential increased, the odds of groups being found in waters deeper than 20 m increased by a factor of 1.96.

DISCUSSION

The results of this study provide quantitative evidence for dusky dolphin nursery groups selecting shallower waters, with slightly over 77% of nursery groups being encountered in depths less than 20 m. While previously unconfirmed, this is not completely unexpected and the distribution of mother-calf pairs in some cetacean studies has also been shown to correlate with shallower waters in certain species including humpback whales (Ersts & Rosenbaum, 2003), grey whales (Swartz, 1986), and bottlenose dolphins (Mann et al., 2000). In my study, nursery groups were the only group type found significantly more often in shallow waters. The biological explanations for this type of relative distribution are likely complex and at this stage preliminary. However, I believe that this study contains important information regarding the types of variables that may influence the relative distribution of nursery groups of dusky dolphins off Kaikoura. Here, I consider each hypothesis and the results of my predictions.

Male hypothesis

A higher proportion of nursery groups than mating groups, adult groups, or large groups were encountered in shallow waters. The number of nursery groups was closely correlated with encounter rates for the large groups by season/times of the year. There were more mating groups and adult non-mating groups in the study area until mid-February. Males may be attracted to females in the weeks following parturition due to hormone level changes in the females at this time. The large number of adult non-mating groups in the area may be a better indicator of potential harassment from males. They are likely seeking receptive females in small groups, even though I did not come across the mating behaviours that would likely ensue if they were successful in finding a receptive female. Markowitz (2004) reported that actual mating activities only lasted 13 minutes on average, and so it can be assumed that I would have missed matings in the area.

The results of the logit regression indicate that, when graded on a likelihood scale of how much potential harassment a given dolphin group was assumed to present to an adult female dolphin, groups with higher "harassment potential" were better predictors of deep water. Biologically, this may be interpreted as saying that by staying in shallow waters, a female dolphin has a lower likelihood of being harassed. From this perspective, waters less than 20 m may be considered a refuge from males.

It has been suggested that mother-calf pairs of humpback whales segregate spatially from other types of social groups in order to avoid harassment from males (Ersts and Rosenbaum, 2003). In bottlenose dolphins in Shark Bay, females were "attractive" (a term used by the authors to describe the female's sexual appeal to a male) to males when their calves were 2-2.5 years old or within weeks of their calf dying (Connor et al., 1996). However, males were also attracted to females in situations not predicted by the oestrous cycle, such as the day following the death of a nursing calf, and the authors suggest that multiple cycling is more likely in this group of dolphins than seasonal cycling (Connor et al., 1996). Another study of individuals in this Shark Bay population investigated the relative amount and type of flesh wounds present on

photographs of dolphins, and used this to indirectly examine the effects of reproductive status on conspecific agonistic behaviour (Scott et al., 2005). They found that cycling females (as determined by those that were pregnant within 6 months of the photo being taken) had more rake-marks than non-cycling females (those that were pregnant or had a dependent calf younger than 20 months). Sexual coercion of adult females by males was suggested as an explanation (Scott et al.2005).

Sexual coercion on the level described for Shark Bay animals was not observed in the present study. However, I observed aggressive apparent coercion behaviour by small groups of probable males that was directed towards females with very young calves. This has also been documented by Markowitz (2004).

Boat hypothesis

Both boats and nursery groups were encountered significantly more often in depths under 20 m, and therefore it does not seem likely that nursery groups are seeking refuge in the shallows from "numbers of boats." However, the multivariate analysis that compared all dolphin groups types encountered in deep and shallow waters predicted that having at least one other boat within 500 m of the group was a good indicator that the group was in deeper waters. In water depths under 20 m, the greatest number of boats encountered were private recreational boats; whereas, in waters deeper than 20 m, most boats were commercial tour boats. Thus, while there may actually be more boats present in the shallower waters, dolphin groups are more likely to be in close proximity to boats when in deeper waters. This is likely caused by private recreational boats in the shallows not targeting dolphin groups while boats in deeper water often are.

Other studies of delphinids have compared the behaviours of females versus males when approached by tour boats. Williams et al. (2002) found that female killer whales on the west coast of Canada travelled significantly faster when boats were within 100m. Lusseau (2003) suggests that females have different strategies for avoiding tour boats in Doubtful Sound, New Zealand, due to their different energetic demands, with females making significantly longer dives when tour boats operators infringe upon the

marine mammal regulations in the area. It is thus likely that female dusky dolphins, especially those with young calves, are affected differently by the presence of tour boats.

The results of the present study may indicate that by staying in shallow waters, a female dolphin has a lower likelihood of being within 500 m of a boat. From this perspective, waters less than 20 m may be considered a refuge from boats.

Predator hypothesis

Due to the elusive behaviour and rarity of encounters with predators in the study area, I was not able to statistically test the predictive power of their presence on the distribution of dusky dolphin group types. Only 1 out of the 9 groups of killer whales recorded in the area during 2006 was encountered in depths under 20 m, with the rest being recorded in deeper waters. All of the sharks recorded in 2006 were in deep waters. These data imply that shallow waters may be an area of refuge from predators, but more information is needed relative to potential predators and nursery groups.

Other reasons for nursery groups frequenting the shallows

The hypotheses examined in the present study are not an exhaustive list of the factors that could be affecting nursery group formation and their presence in shallower waters. For example, nursery groups may be using the shallows as a foraging ground. In a study of bottlenose mother-calf pairs in Sarasota Bay, Florida, the use of shallow areas was higher when females were foraging compared to when they were not (Weiss, 2006). Habitat partitioning by different social groupings has been correlated with grazing habitat types and by distance to drinking water in African elephants (Ersts & Rosenbaum, 2003). The idea that dusky dolphin nursery groups are supplementing their diet while spending time in the shallows is explored more in the following chapter.

Future analyses might investigate the predictive power of other variables such as distance from the boat ramps, distance from shore, distance from the large group, bottom type, and temperature pattern.

CONCLUSION

Off Kaikoura, New Zealand, dusky dolphin nursery groups occur most often in waters less than 20 m deep. Females with young calves may be forming nursery groups to evade harassment by conspecifics, especially during the summer months, when males are likely in oestrous but females with newborn calves are likely not. Nursery groups may also be safer from predators when in the shallower waters, since predators were almost always in deeper waters. The reproductive success of female bottlenose dolphins in Shark Bay, Australia, was predicted by water depth, with mother-calf pairs in shallower waters having a higher chance of surviving to their 3rd birthday (Mann et al. 2000). The shallow waters off Kaikoura are also the area most frequented by private recreational boats. Fishing practices and associated gear are likely hazardous for young dusky dolphin calves and their mothers in this area, as has been illustrated for New Zealand fur seals, *Arctocephalus australis* (Boren et al., 2006) and Hector's dolphins, *Cephalorhynchus hectori* (Slooten et al., 2006). Managers should focus efforts on protecting this vulnerable subgroup of the dusky dolphin population by protecting their preferred near-shore shallow habitat and reducing potential impacts from human-use.

CHAPTER III

SUBGROUP FORMATION IN A MESOPELAGIC DELPHINID: NURSERY GROUP COMPOSITION AND BEHAVIOUR

INTRODUCTION

The bond between mothers and infants is the closest of associations in cetacean societies (Connor et al., 2000). Beyond this, animals of a similar age class or sex often form groups of varying levels of cohesiveness. Nursery groups consist of mothers and young that form distinct spatial groupings, separated physically, although not necessarily acoustically, from other individuals of the same species in the greater area. Examples of terrestrial animals that form nursery groups include Rocky Mountain big horn sheep (*Ovis canadensis*) (Ruckstuhl & Kokko, 2002), golden takins (*Budorcas taxicolor*) (Zeng et al., 2002) and African elephants (*Loxodonta Africana*) (Sigbjorn & du Toit, 2002). Many species of primate groups also form female-bonded groups including vervet monkeys (*Cercopithecus aethiops*), olive baboons (*Papio anubis*), rhesus monkeys (*Macaca mulatto*) and ringtailed lemurs (*Lemur catta*) (Wrangham, 1980).

One theory for why segregation occurs between the sexes is that males and females, especially those who are pregnant or lactating, behave differently from one another. Theoretical modelling has indicated that asynchrony in activity budgets could lead to sexual segregation in animal populations (Ruckstuhl & Kokko, 2002). Females with young may alter their behaviours, and hence form nursery groups to satisfy the higher energetic demands of lactation. Amount of time foraging, and/or specific food types chosen, have been observed to differ between pregnant and lactating females and males of the same population. For example, within a study population of Rocky Mountain bighorn sheep (*Ovis canadensis*), lactacting ewes took more bites of vegetation per minute than did males or non-lactating females (Ruckstuhl et al., 2003). Male and female grey seals (*Halichoerus grypus*) have also demonstrated different spatial and dietary niches (Breed et al., 2006), with females selecting higher-quality prey

than their male counterparts. In spotted dolphins (*Stenella attenuata*), lactating females had a diet of mostly flying fish, while pregnant females and other members of the population fed on mostly squid (Bernard & Hohn, 1989). Females may also compensate for the cost of lactation by spending a greater proportion of their time resting than in other behavioural states. In a study of bottlenose dolphin mothers and calves, both mothers and dependent calves spent the largest percentage of their time in a resting state (Mann & Smuts, 1999).

Another theory for why segregation occurs is that there is an innate preference among individuals to associate with peers of the same sex, and perhaps of the same reproductive condition (Bon & Campan, 1996). The most obvious association pattern observed in delphinid nursery groups is often based on reproductive condition, with females swimming with other females who have calves of roughly the same age (Würsig & Würsig, 1980; Pryor & Shallenberger, 1991; Wells, 1991). In species where relatedness is known, longer term associations within nursery groups are frequently composed of related females. For example, the fundamental units of sperm whale (*Physeter macrocephalus*) societies are groups composed of females and their descendent young (Whitehead & Weilgart, 2000). Within groups of bottlenose dolphins in Sarasota, genetic studies have shown that at least some of the adult females who spend time together in groups are related to one another (Wells, 1991). Studies of bottlenose dolphins have also indicated that calves of females who associate at a young age often continue to be closely associated later in life (Wells, 1991; Mann et al., 2000).

On the east coast of New Zealand's South Island, near the town of Kaikoura, hundreds of dusky dolphins spend their days near shore resting and socializing and their nights feeding further offshore on a deep layer of mesopelagic fish and squid (Würsig et al., 1997; Benoit-Bird et al., 2004). During the day, the largest groups of dolphins are visited by dozens of boats and hundreds of paying tourists, with potentially over 100 people entering the water to swim with them daily (Duprey, 2006). Nursery groups are not generally the target of tour operations and these small sub groups have been

relatively understudied compared to the larger groups. This chapter examines the association patterns and behaviours of nursery groups in this area.

After a 7-month preliminary exploratory study of the behaviours of dusky dolphins in New Zealand, I spent another 10 months conducting systematic surveys of the area and collecting records on the group composition and membership in nursery groups using photo-identification techniques detailed by Würsig and Jefferson (1990). I also conducted group focal follows (Whitehead, 2004) to quantify both the behavioural states of nursery groups and the main types of activity observed in these particular groups. In this chapter, I 1) describe the association patterns for nursery groups; 2) quantify the behaviours of nursery groups; and 3) compare the behaviour of nursery groups to that of other types of groups in the area and to mother-calf behaviour in other delphinid species.

METHODS

Photo-identification

An attempt was made to photograph each member of each nursery group encountered during the study period of January–May 2005 and December–April 2006 in order to identify individuals within these groups (Würsig & Jefferson, 1990). A Nikon D1H digital camera with a 100–400 zoom lens was used to photograph the dorsal fins and body scarring on individual dolphins. Clear digital photographs of individuals were then sorted into categories and labelled to describe the date and group that each individual was photographed (ex. yyyy mm dd group ID and group individual number; ex. 2005 02 26 B4). Individuals were further categorized based on their markings as being: 1) gnarly; 2) leading edge; 3) top chop; 4) one large notch; 5) one small notch; 6) entire trailing edge; or 7) body marks (Figure 5). Re-sight information was calculated by comparing each photograph to all other photographs in the catalogue by eye, using a laptop computer. An Access database was created to catalogue all individuals occurring in nursery groups during my two field seasons in Kaikoura.

Figure 5. Examples of individuals from each mark category used. The order shown here was the order of prioritization when sorting photographs. a) gnarly, b) leading edge, c) top chop, d) one large notch, e) one small notch, f) entire trailing edge, g) body marks.

Behavioural sampling

While conducting surveys of the area (see Methods for Chapter II), I attempted to conduct a 30-minute group focal follow for every nursery group encountered. The ethogram that I developed for this study is shown in Table 9. During focal follows, I recorded all instances of certain infrequent behaviours including displays, head-first re-entries, and coordinated leaps. For displays and head-first re-entries, I recorded whether it was a calf or an adult. At 5-minute intervals, I recorded the behavioural state of the group via scan sampling (Altmann, 1974). Behavioural state was classified as being one of traveling, resting, socializing or foraging. At these same 5-minute intervals, I also recorded the group location using a GPS, group structure, group direction, group composition and whether or not the group was synchronizing their submergences and surfacings at that time. When possible, I recorded the length of each surfacing and dive interval. Unusual instances were recorded as they occurred, while continuing to conduct the focal follow. When the 30-minute group focal follow was finished, I returned to the survey route and continued to survey the area.

Table 9. Ethogram used for focal follows of nursery groups. Descriptions of behaviours are based on 7 months of preliminary field work with the dolphins in the area as well as behavioural descriptions of dusky dolphins by Cipriano (1992) and bottlenose mothers and calves by Mann and Smuts (1999).

Behaviour	***Description***	***Type of Sampling***
Display	Surface behaviour that involves slapping a body part (belly, dorsal, side, tail, pectoral flipper) on the water surface. Includes spyhops.	All occurrence sampling
Head first re-entry	Leap out of the water, with the entire body of the dolphin leaving the water and re-entering with a clean (minimal splash) head first dive.	All occurrence sampling
Coordinated leap	Two or more dolphins doing head first re-entry leaps in unison.	All occurrence sampling
Traveling	Straight movement, >3 km/hr, no changes in direction.	Predominant behavioural state every 5 minutes
Resting	Slow travel, < 3 km/hr, frequent floating at the surface, frequent direction changes, extended duration (>30 seconds) shallow submergence with little movement in any particular direction. No tail-up dives and regular breaths upon re-surfacing.	Predominant behavioural state every 5 minutes
Socializing	Attention of animals focused on one another, frequent direction changes. Frequent pectoral fin rubs, touching between individuals including rolling at surface, belly up swimming, chasing of other individuals in the group.	Predominant behavioural state every 5 minutes
Foraging	Extended duration (>30 seconds) deep submergence with little movement in any particular direction. Tail-up dives and loud breaths upon re-surfacing. Sometimes also fast burst swims and head first re-entry leaps.	Predominant behavioural state every 5 minutes
Pack	Closely spaced (< 1 adult body length apart) dolphins that move as a unit.	Instantaneous sampling
Parallel	Closely spaced (<1 adult body length apart) dolphins that are moving together in a tight side-to-side formation.	Instantaneous sampling
Scattered	Dolphins spread out (> 1 adult body length apart) and moving independently or in small sub-groups within the greater group.	Instantaneous sampling
Extended	Dolphins spread out (> 1 adult body length apart) in a long narrow line, usually moving as a unit.	Instantaneous sampling
Synchronized breathing	All group members submerging within 5 seconds of one another, staying submerged for longer than 20 seconds and eventually re-surfacing, all within 5 seconds of one another	Instantaneous sampling
Harassment	Sudden fast/burst swim by group members accompanying the arrival of new adult dolphins. Chasing of group members by new adult dolphins and possibly attempts to separate members by moving aggressively between mothers and calves.	All occurrence sampling

RESULTS

Size of nursery groups

A nursery group consisted of no more than 3 non-calves per calf with a minimum of two calves. The mean size for a nursery group was 20.7 (SD= 20.06). The median group size was 14, with a maximum of 100 and minimum of 4 individuals. The median group size varied by month and season with much larger groups of 80+ individuals forming in April 2005 and in the end of March and early April 2006 (Figure 6). These larger groups did not appear to replace the smaller nursery groups; rather, they were additional large aggregations of mothers and calves. These large groups were always located at the mouth of the Kahutara River.

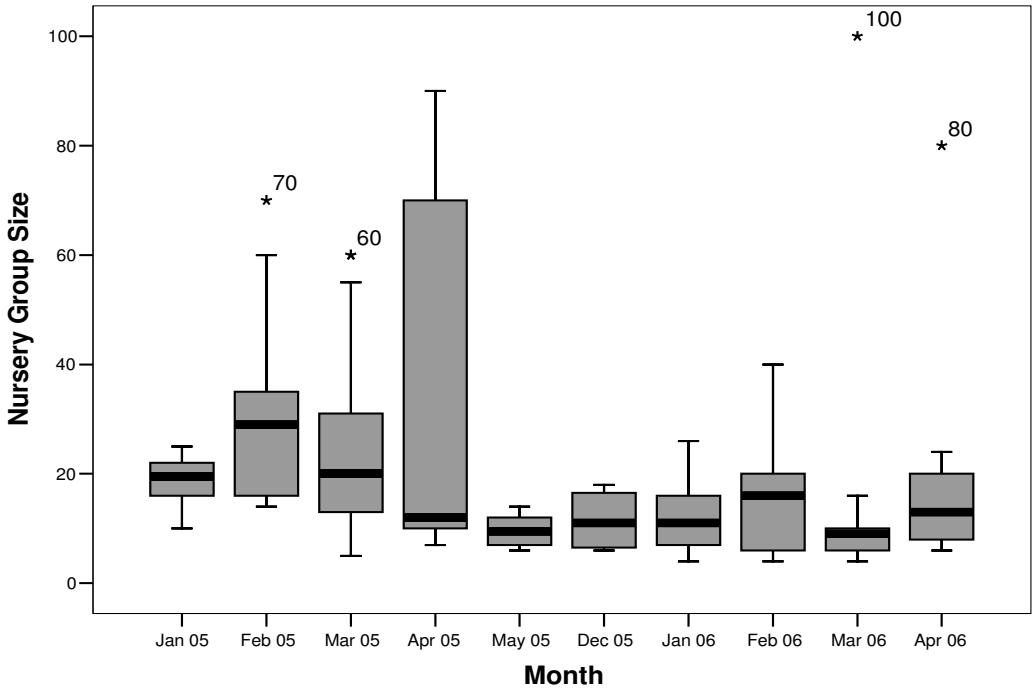

Figure 6. Size of nursery groups by month. Medians are shown by black bars. The grey boxes represent the inter-quartile range and the whiskers represent the 95 percentile ranges. Stars represent outliers. Group sizes represent the total size of the group upon initial encounter (N=128).

Photographic effort

One hundred and thirty nursery groups were recorded between 2005 and 2006 (71 between January and May 2005 and 59 between December 2005 and April 2006).

Of these, I obtained photographs of distinctly recognizable individuals for 99 groups. Two hundred and sixty individuals were catalogued as members of nursery groups between January 2005 and April 2006. Of these, 178 were recorded in 2005 and 82 in 2006.

Mark rate

Of the mark type categories, the highest percentage of marked adults fell into the "entire trailing edge" category 35% (n=251). The others fell somewhat uniformly into "gnarly" (0.6%), "leading edge" (13.5%), "top chop" (13.5%), "one large notch" (11.6%), "one small notch" (10.3%) and "body marks" (10.3%).

Of the 260 individuals catalogued, only 9 of these were calves. Only 2 of these 9 were well marked, with the remaining 7 being in the "body marks" category. These marks are likely to heal as the calf grows and are therefore not very good identification markers over the longer term. Healing in dolphins and especially calves appears to be exceptionally rapid. During our 2006 field season we witnessed the healing of one particular calf over 3 months. The dolphin with the initial injuries was first recorded on February 13, the same day that a group of 18 killer whales were observed in the study area. Re-sightings of this individual allowed the documentation of significant healing over a relatively short period of time (Fig. 7).

The other marked calf of this study had an adult accompanying it that was also well marked. This adult was presumed to be the mother, because the two were sighted in the same nursery groups together and the calf was consistently in echelon position with this adult (Fig. 8).

a.)

b.)

c.)

d.)

Figure 7. Photographs of an injured calf. Photographs were taken on February 13th (a and c) and on April 4th (b and d), showing the healing of a severe injury likely from an attack by a killer whale.

Figure 8. Marked adult with marked calf. The only marked mother-calf pair observed during our study.

Re-sights of individuals in Kaikoura

One hundred and twelve individuals were photographed in nursery groups on at least 2 different days during the course of this study. The highest number of re-sights for a single individual was 8. A total of 39 individuals were photographed in nursery groups in a minimum of 3 different calendar months during the study period (Table 10). A total of 49 individuals were photographed as members of nursery groups in both seasons of field work. Table 11 shows the individuals that were recorded in 2005 and 2006 off Kaikoura, and the months that they were recorded.

Is nursery group membership stable over time?

From the analysis carried out to date, it appears that certain individuals are photographed in nursery groups off Kaikoura more often than others. Only 57% of individuals were photographed in nursery groups once (n=148), while others were photographed in nursery groups up to 7 times in one field season. It remains to be determined whether this is a function of mothers and calves moving through the area of Kaikoura or simply associating with the larger groups off Kaikoura. We have some preliminary photographic evidence that at least some of the females who are photographed in nursery groups are also occasionally observed in the larger groups.

Regarding associations between individuals, it appears that while nursery group membership can be stable over a period of 30-minutes, with no new individuals joining or leaving the group, over periods of days or months we see interesting dynamics in "who associates with whom" in nursery groups. I calculated the half-weight coefficient of association (COA) for a few of the best marked individuals, using methods detailed by Smolker et al. (1992). The calculation used is 2Nab/Na+Nb, where Nab represents the number of times dolphin "a" and dolphin "b" were photographed in the same nursery group, and Na and Nb represent the number of times dolphin "a" and dolphin "b" were photographed in nursery groups, in total. I found that COAs range from 0, with certain well-marked individuals never together in the same nursery group, to COAs of 86 for some females with young calves who were almost always found together in the same

Table 10. Individuals identified in nursery groups off Kaikoura in at least 3 separate months between the 2005 and 2006 field seasons. An "X" indicates that the individual was photographed in a nursery group at least once during that calendar month (N=39)

ID	Name	2005						2006			
		Jan	Feb	Mar	Apr	May	Dec	Jan	Feb	Mar	Apr
1	Akona	X					X	X			
114	Tahuna	X	X							X	X
2	Rangi	X	X					X			
118	Para		X					X		X	
160	Ika		X	X	X						
8	Makariri		X	X	X						
84	Zinny		X	X				X		X	
30	Fyffe		X	X				X		X	X
5	Ao		X	X				X			
79	Nehu		X		X	X		X			
80	Puna		X		X	X			X		X
81	One		X		X			X	X		X
82	Oriwa		X	X				X	X		
83	Oru		X					X	X		
4	Pukaki		X	X					X		
53	Tongi			X				X			X
19	Kaihau			X	X	X					
38	Mahu			X	X	X		X			
94	Panga			X	X	X					
103	Huuka			X	X					X	X
162	Pumpkin			X	X			X			
31	Snwflake			X	X			X	X		
34	Koki			X	X					X	
99	Lomu			X	X		X				
87	Pahi			X	X						X
111	Kakama				X	X		X		X	
139	Tira				X	X		X	X	X	
130	Hau				X			X	X		
40	Mangoo				X			X	X	X	
146	Tiitongi				X			X			X
90	Paina				X			X	X		
93	Pakini				X					X	X
140	Tara					X		X		X	
110	Wilson					X		X		X	
172	Sarah							X		X	X
207	Wangari							X	X		X
222	Sun							X	X	X	
241	Frida							X	X	X	

Table 11. Individuals identified in nursery groups off Kaikoura in both 2005 and 2006 field seasons. An "X" indicates that the individual was photographed in a nursery group at least once during that calendar month (N=49)

ID	Name	2005						2006			
		Jan	Feb	Mar	Apr	May	Dec	Jan	Feb	Mar	Apr
1	Akona	X					X	X			
114	Tahuna	X	X							X	X
2	Rangi	X	X					X			
118	Para		X					X		X	
122	L-Moa		X					X			
26	Aawhaa		X					X			
83	Oru		X					X	X		
3	Akiaki		X					X			
4	Amarama		X					X			X
30	Fyffe		X	X				X		X	X
95	Pukaki		X	X					X		
5	Ao		X	X				X			
82	Oriwa		X	X				X	X		
84	Zinny		X	X				X		X	
79	Nehu		X		X	X		X			
80	Puna		X		X	X			X		X
81	One		X		X			X	X		X
102	Piki			X						X	
53	Tongi			X				X			X
43	Kupenga			X						X	
36	Kohu			X						X	
38	Mahu			X	X	X		X			
103	Huuka			X	X					X	X
162	Pumpkin			X	X			X			
31	Snwflake			X	X			X	X		
34	Koki			X	X					X	
87	Pahi			X	X						X
106	Matau				X						X
130	Hau				X			X	X		
90	Paina				X			X	X		
139	Tira				X			X	X	X	
40	Mangoo				X			X	X	X	
14	Ara				X						X
137	Matikuku				X						X
93	Pakini				X					X	X
143	Tutu				X						X
146	Tiitongi				X			X			X
131	Pono				X			X			
149	Taringa				X						X
167	Puukiki				X						X
21	Hawa				X			X			
111	Kakama				X	X		X		X	
110	Wilson					X		X		X	
23	Haukuu					X				X	
25	Hihi					X				X	
140	Tara					X		X		X	
109	Koko-a					X		X			
183	Wendy						X	X			
219	Ella						X	X			

nursery group. I found at least one pair of individuals who occurred together in nursery groups in both February 2005 and January 2006. While the COA for this pair of individuals is 50 (i.e., they are not *always* found together), their association in nursery groups nearly a year later is an interesting preliminary step towards unravelling the social dynamics within nursery groups.

Travelling nurseries? Some evidence for nursery groups in Admiralty Bay

Admiralty Bay is a shallow bay area in the Marlborough Sounds, on the northern coast of New Zealand's South Island (~275 km swim from Kaikoura). Dusky dolphin research is also underway in this area, and photographs of dusky dolphins in Admiralty Bay yielded some comparative information. Two individuals which had been photographed in Kaikoura during the summer/fall season of 2005 were recorded in Admiralty Bay later in the year. Ika, a well-marked individual, was photographed with a young calf off Kaikoura in February, March and April 2005. In October 2005, she was photographed in Admiralty Bay. She was also photographed in Admiralty Bay in February 2006. Ika was not sighted in Admiralty Bay from June-July 2005, nor was she seen off Kaikoura from January-April 2006. Tekapo, another well-marked individual, was photographed with a young calf in nursery groups off Kaikoura in February and March 2005, and then in Admiralty Bay in June of the same year.

Focal follow effort

For analysis of behaviours, I only used focal follows that lasted a minimum of 30 minutes. For follows that lasted longer, only the first 30 minutes were used for these analyses. In total, this study resulted in 56 focal follows of at least 30 minutes (37 in 2005 and 19 in 2006).

General behaviour of nursery groups

When focal follows were analyzed for predominant group behaviour, I found that among the groups that showed a predominant behaviour (they were engaged in the same

behavioural state for at least 2/3 of the focal follow, i.e., 4 out of 6 scan samples), 68.2% were resting, 18.2% travelling, 9.1% socializing and 4.5% were foraging (Fig. 9). Forty four groups of 56 showed a predominant behaviour.

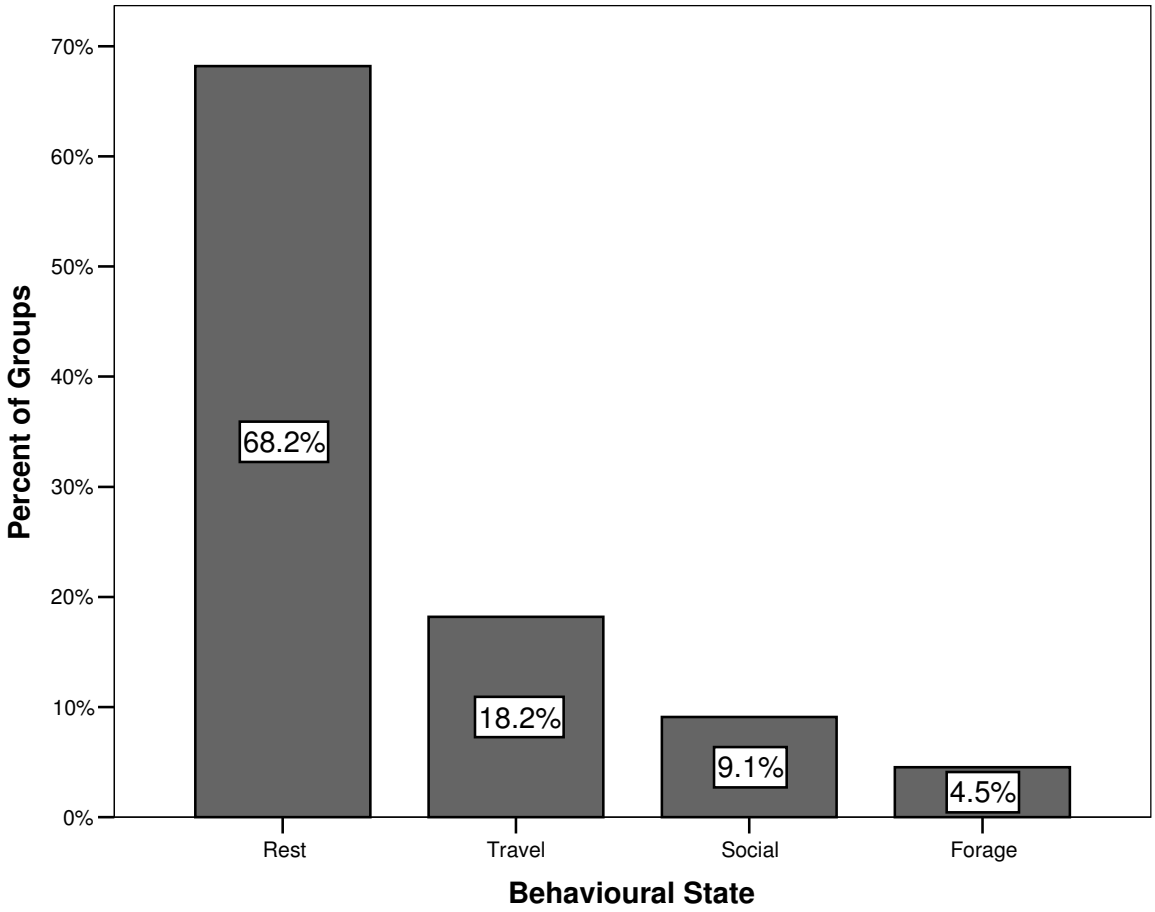

Figure 9. Behavioural state of nursery groups during 30-minute focal follows (N=44). Groups that did not exhibit the same behavior for at least 2/3 of the focal follow were excluded from this analysis (N=12).

For 54 nursery groups, we recorded whether the group was synchronizing their submergence and surfacing behaviours. Of these 54 groups, 44% synchronized their surfacings for the majority of the focal follow (i.e., at least 4 out of 6 scan samples).

Feeding by females in nursery groups would likely take place beneath the surface. In my study area, water clarity does not allow us to see deeper than about 2 m even on the clearest and calmest days. Evidence of foraging therefore was extended to behaviours that were indicative of foraging at depth, including tail-out dives upon submergence, and loud breathing upon resurfacing. In Figure 10, I compare 10 different nursery groups that were recorded submerging and resurfacing in near-exact synchrony for at least 10 dives. For the first group, labelled "Apr19A," I also recorded foraging type dives based on our previous surface descriptions. The other 9 groups shown in this figure were classified as resting.

Although only 2 groups showed foraging as a predominant behaviour, 5 other groups showed foraging for at least one of the scans in the focal follow. This is important because dusky dolphins generally do not forage during the day off Kaikoura. During one focal follow in February 2006, an adult (presumed to be a mother based on her close proximity to a calf at all times) surfaced within 2 meters of our research boat with a large fish (approximately 30 cm) held cross-wise in her mouth. This occurred at the mouth of the Kahutara River, an area where fish are found in concentrated numbers (personal communication, local fishermen).

When focal follows were analyzed for predominant group structure, 47.1% were in pack formation, 29.4% were in parallel formation, 2.9% were in extended formation, and 20.6% were scattered for at least 2/3 of the focal follow (Fig.11). Thirty-four of 56 groups showed a predominant group structure.

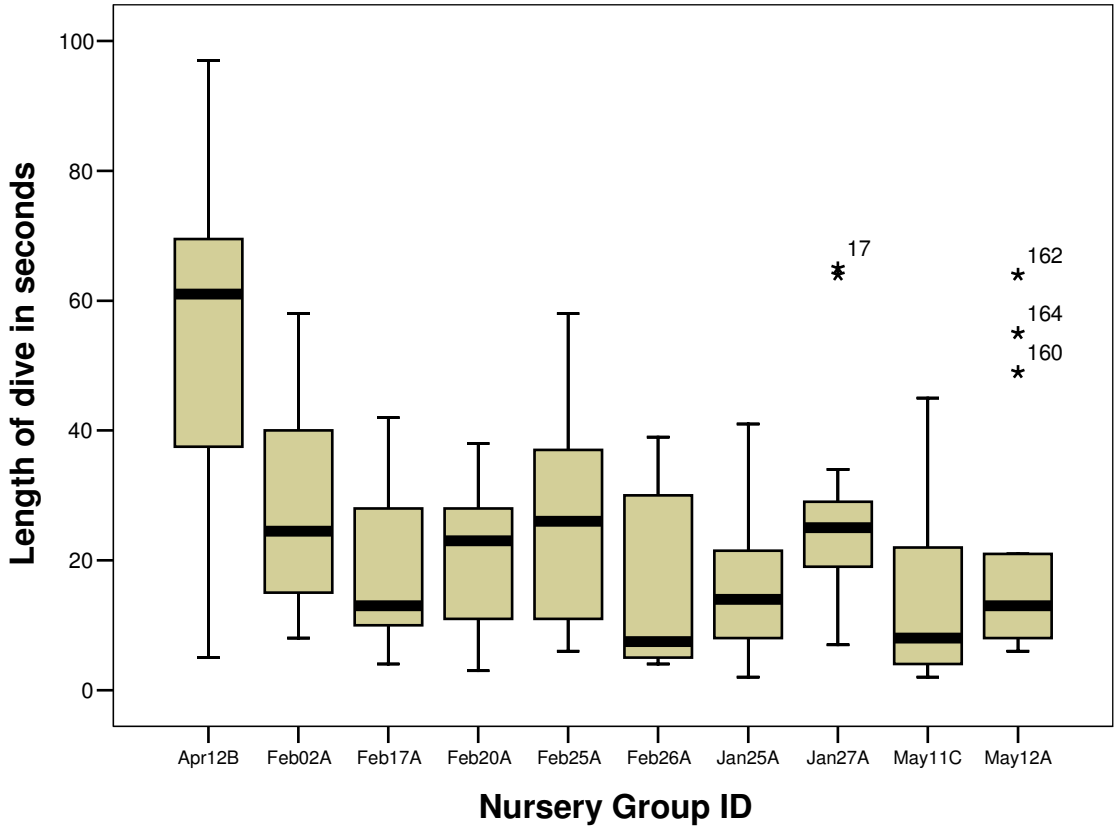

Figure 10. Lengths of synchronized dives recorded for 10 nursery groups during 2005. Records for a minimum of 10 dive lengths were required for a group to qualify for this analysis. The predominant behavioural state of all of these groups was "rest", except for Apr12B, which was "forage". Median length of dives for each group are shown by black bars. The grey boxes represent the inter-quartile range and the whiskers represent the 95 percentile ranges. Stars represent extreme outliers.

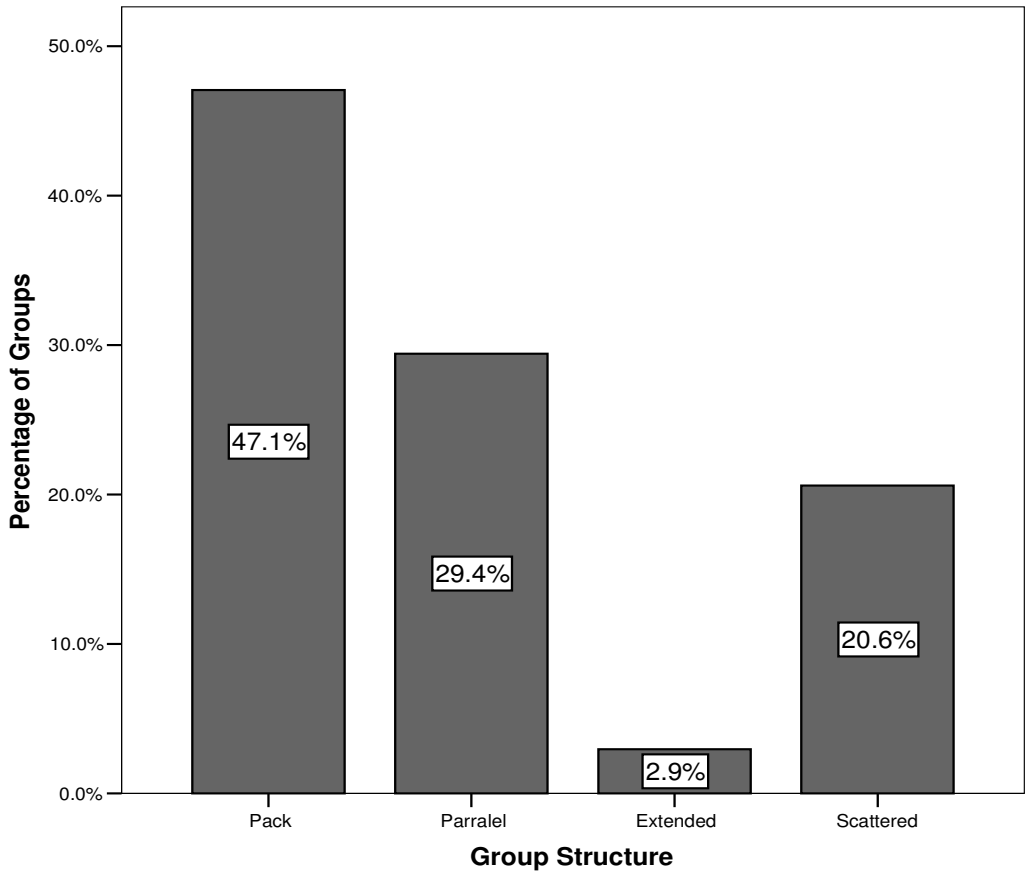

Figure 11. Group structure of nursery groups during 30-minute focal follows (N=34). Groups that did not exhibit the same group structure for at least 2/3 of the focal follow were excluded from this analysis (N=22).

Daily patterns of behaviour

To investigate whether nursery groups were resting more during midday, I plotted the time of day against percentage of groups. There was no difference in amount of rest by time of day (Fig. 12).

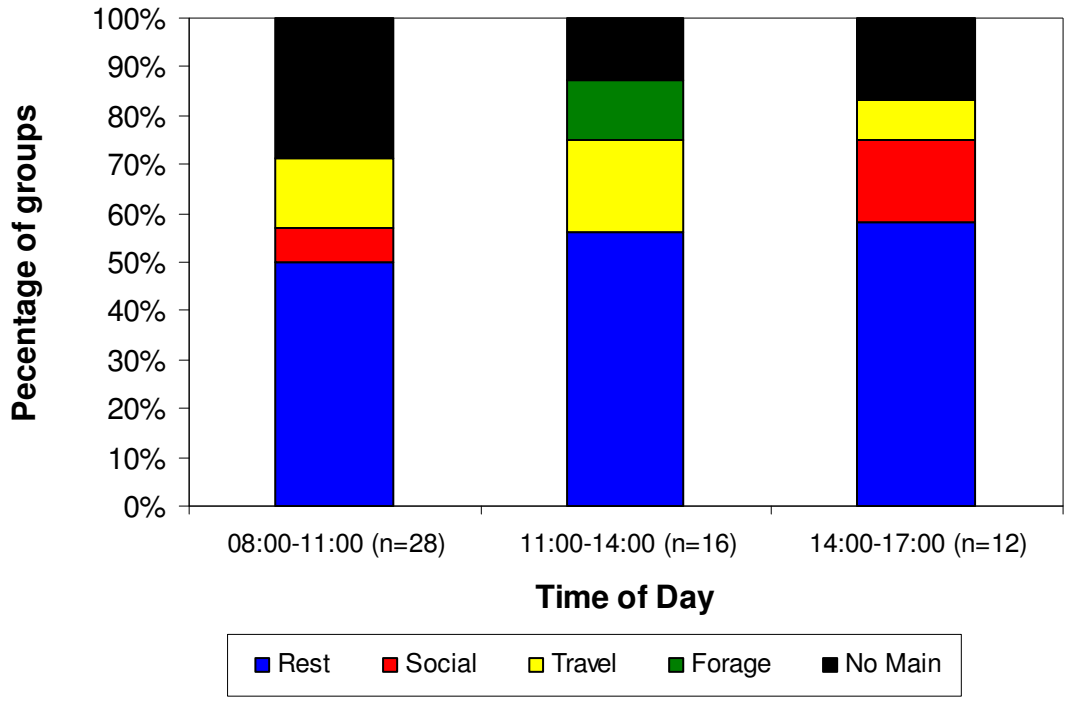

Figure 12. Predominant behavioural state of nursery groups during focal follows in 2005 and 2006 (N=56) displayed by time period.

Seasonal shifts in behaviour

Behaviour of nursery groups differed throughout both field seasons (Fig. 13). February 2005 had 90% of nursery groups resting but in March there was less resting and more travelling and socializing. In 2005, a gradual increase in rest occurred between March, April and May; but in 2006 this gradual elevation was one month earlier, in February, March and April. This timing coincided with the appearance of very large nursery groups (80+ individuals; Fig. 6 above).

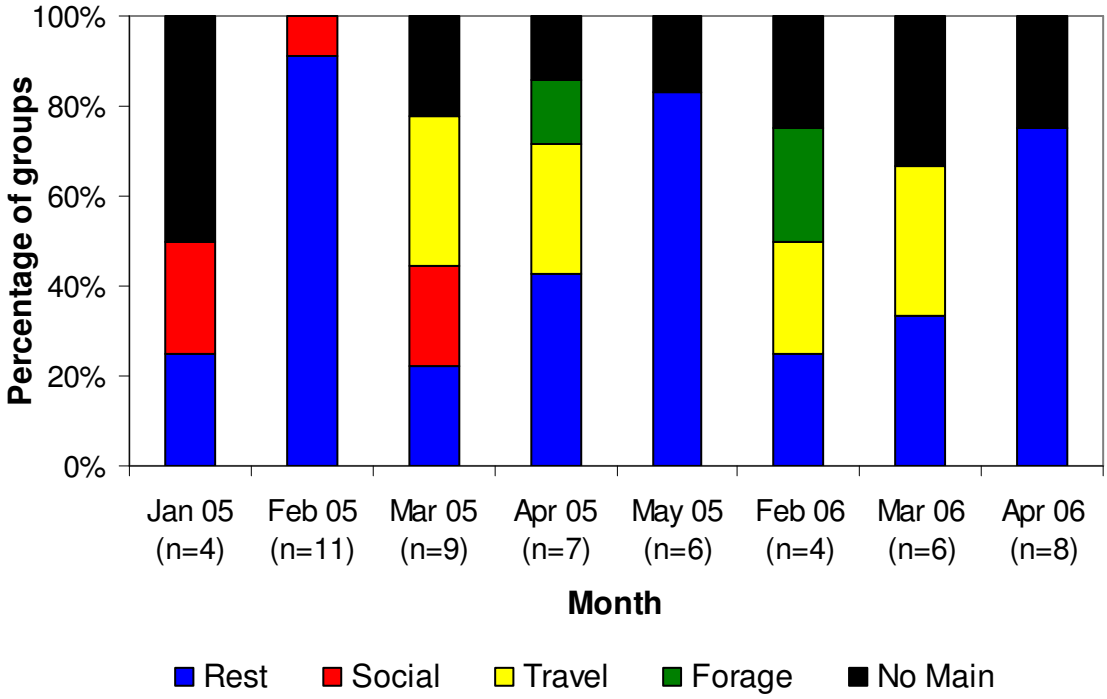

Figure 13. Predominant behavioural state of nursery groups during focal follows in 2005 (N=37) and 2006 (N=18) by month. A category for January 2006 is not displayed here due to small sample size (N=1, no main behavior).

High energy behaviours, a comparison of calves vs. non-calves

Displays and head first re-entries were counted per calf and non-calf (juveniles and adults) during each 30-minute focal follow. There was no strong correlation between the number of displays per calf and the number of displays per non-calf (R^2 linear=0.188), or the number of head first re-entries per calf and the number of head first re-entries per non-calf (R^2 linear=0.106). In comparing the number of displays made by calves and non-calves during a focal follow, calves performed significantly more displays than non-calves (Mann-Whitney U p=0.01, Table 12) and only a slightly more significant number of head first re-entries (Mann-Whitney U p=0.05, Table 13). When all high energy behaviours, displays and head first re-entries were combined, the

mean number of high energy behaviours by calves was significantly higher than that of non-calves (Mann-Whitney U p=0.02, Table 12).

Table 12. Mean number of displays, head first re-entries and total high energy behaviours per calf and per non-calf during 30-minute focal follows (N=46). Focal follows for which high energy behaviours were not recorded due to the large size of the group were excluded from this analysis (N=10).

	Per Calf (S.E.)	Per Non-calf (S.E.)	p-value
Mean displays	0.11 (0.03)	0.02 (0.00)	0.01
Mean head first re-entries	0.09 (0.02)	0.04 (0.01)	0.05
Total high energy behaviours	0.20 (0.04)	0.05 (0.01)	0.02

DISCUSSION

I was able to highlight and describe behaviours and patterns of association that are specific to nursery groups off Kaikoura.

Sociality of nursery groups

Nursery groups are composed of approximately 14 (median, range 4–100) individuals. This is larger than recorded sizes of mother and calf groups of bottlenose dolphins off Shark Bay and Sarasota, where the mother calf pairs associate with each other for almost half of their time (Connor et al., 2000). When they do associate with other individuals, it is in small groups of approximately 3-7 individuals (Connor et al., 2000). In the present study, we only recorded solitary mother-calf pairs on 2 separate occasions, and this was not the norm for the area, with most mother-calf pairs being found together in nursery groups or among the large mixed sex and age groups of over 150 individuals. In Argentina, Würsig and Würsig (1980) described nursery groups of dusky dolphins composed of 8–20 mother-calf pairs. They too noted that mother-calf

pairs were sometimes present in the larger groups of dolphins in the area. Nursery-type groups have also been described for marine tucuxis (*Sotalia fluviatilis*) (Azevedo et al., 2005) and humpback dolphins (*Sousa chinensis*) (Karczmarski, 1999). Karczmarski (1999) found that groups with calves had a mean size of 10 individuals, whereas groups without calves present were significantly smaller, at only 4.7 individuals. Calves only represented, at a maximum, 33% of the individuals in a "nursery group." This is less than the present study of dusky dolphin nursery groups, where many groups were composed of 50% calves (i.e., all mother-calf pairs).

At least some of the females in nursery groups were associating with certain companions (females with calves of roughly the same age) more frequently than others, with COAs reaching as high as 80. I found some evidence that associates are consistent over periods of days and to at least 11 months. Even though further analysis is needed to extrapolate from these preliminary findings, my impression is that there are more significant associations occurring than have been recorded, judging by the fact that my analysis is preliminary and only accounts for very well-marked individuals.

Behaviours of nursery groups

This study confirmed that the predominant behavioural state observed in nursery groups is "rest." While previous studies have indicated this as well (Markowitz, 2004), the larger data set of the present study allowed us to investigate these behavioural patterns across different periods of the day and across months and seasons. Nursery groups do not demonstrate a change in behavioural state that coincides with the mid-day period as has been described by Barr and Slooten (1999) for the larger groups. Instead, nursery groups are usually found resting throughout the morning, midday period, and the afternoon. The increased energetic demands of lactation may influence the movement of mother-calf pairs away from the large group and into smaller groups where there is less high energy activity. Nursery groups may also be employing an anti-predator strategy by staying relatively inconspicuous in their behaviours compared to other group types. In a study of maternal care in cheetahs (*Acinonyx jubatus*), mothers that rested quietly

with their cubs in the lair were less likely to be preyed upon than those that made noise, or went outside of the lair (Laurenson, 1994). Changing their group structure and composition by separating from the large groups and forming nursing groups may also be a way that dolphin mothers may increase their vigilance. Laboratory studies of schooling fish have demonstrated that shiners (*Notropis heterodon*) change their group formation in the presence of a predator to maximize vigilance at the cost of decreased hydrodynamic efficiency (Abrahams & Colgan, 1985).

The trend of behaviour appears to show increased numbers of "resting" nursery groups as we progress from summer to fall. This increase may correspond to the aging of calves, who are very young, vulnerable, and less developed during January and February but gradually become less vulnerable as they develop better motor skills by April and May. The variability in group behaviour during the summer months may also be due to heightened vigilance and protectiveness of mothers during this early period in their calf's life. In a study of bottlenose dolphin mothers and calves, mothers were found to be highly protective of their new calves, which were observed to have a strong "following response" during the first month of their life (Mann & Smuts, 1998). The authors suggest that non-mothers are more likely to successfully "steal" a young infant away from its mother by accelerating near the infant during this early stage. They conclude that there may be an early imprinting period during which the dolphin mother-calf pairs are less likely to associate with other individuals (Mann & Smuts, 1998). It is also possible that mothers and calves do not rest as frequently during the summer months because of increased harassment from males. Markowitz (2004) observed more mating behaviours in summer than in other months.

It is also important to consider how the period of increased rest (during May 2005 and April 2006) occurred just after the periods when the largest nursery group sizes were recorded (during April 2005 and March 2006). During these seemingly transitional times, large nursery groups of up to 50 mother-calf pairs occurred near shore, close to the Kahutara river mouth. The present study only covers 2 consecutive years of data; however, previous researchers (Harlin, 2004; Markowitz, 2004) and local tour operators

report that there is a distinct shift in the behaviours and membership of dusky dolphins found off Kaikoura that happens sometime during the fall months of every year. Along these same lines, most individuals that I recorded in summer 2005 were no longer observed in the study area by May 2005. Many of these particular mother-calf pairs were also not seen off Kaikoura during the entire 2006 study period. In contrast, individuals first photographed off Kaikoura in March and April 2005 occurred in nursery groups off Kaikoura in December, January and February 2006. I suspect that mothers may be using the area off Kaikoura during the earlier development stages of their young calf, and then heading to other regions of New Zealand when the calf is older. We now need to find out if and when the females that gave birth in early summer come back to Kaikoura in upcoming years.

The present study also describes the first foraging behaviours documented for this group type off Kaikoura. While occurrences were rare, and definitions based on surface behaviours, 2 nursery groups showed foraging behaviours throughout the majority of their 30-minute focal follows (5 other groups were foraging during at least one scan of their 30-focal follows). If nursery groups are indeed foraging in the shallows during the daytime, then this would lend support to the theory that nursery group formation is at least partially a result of the differing dietary needs of lactating females. Females may be seeking out extra food to supplement the caloric intake of their night-time diet of mesopelagic fishes and squid. They could also be eating prey that is easier to catch (i.e., closer to the surface) than night-time prey in order to reduce or eliminate time separated from their calves which likely occurs during longer dives to meet the deep scattering layer that adult dusky dolphins have been shown to dive to during the night (Benoit-Bird et al., 2004).

The synchrony of behaviours in nursery groups suggests a high degree of association between members. Recently, Conner et al. (2006) reported that synchronous surfacing in male bottlenose dolphins is associated with alliance membership. The nursery groups in the present study were frequently reported to dive and surface in synchrony. On occasions when this behaviour persisted over 10 dives, median dive

length was similar across resting groups but considerably longer in a foraging group. A completed analysis of association patterns will allow me to investigate whether groups that were recorded submerging and surfacing in synchrony are more highly associated over longer time scales than groups that were recorded not surfacing in synchrony.

I suggest that nursery groups form a specialized type of social grouping that differ not only from other dusky dolphin subgroups off Kaikoura, but perhaps from some other delphinids studied to date. There is a high number of mother-calf pairs forming nursery groups in the area. This area appears to have a very large number of new or very young calves, especially in summer. It may be that the area off Kaikoura is ideal for this specific life stage.

CONCLUSION

Nursery groups off Kaikoura, New Zealand, differ in composition and behaviours from other described nursery groups in delphinid populations. Their median size is 14 individuals with a larger number of mother-calf pairs associating with one another than has been described for humpback dolphins, marine tucuxis, and bottlenose dolphins. Nursery groups were mostly resting, but a few engaged in foraging-type behaviours. Individuals in these groups were usually all within 1 adult body length of each other and often exhibited a high degree of synchrony in their submergences and surfacings. Resting did not decrease around the mid-day period as has been reported for the large groups, but the proportion of nursery groups that were resting increased in the fall months. With 260 distinct individuals recorded in nursery group during my study period and only 9 of these being calves, it appears that over 200 reproductive females employ a strategy of calf rearing that involves separating from the large group, with other mother-calf pairs, to rest, forage, and socialize in the shallow waters off Kaikoura.

CHAPTER IV

CONCLUSION

Nursery groups, composed of mostly mothers and young calves, made up almost 18% of group types encountered off Kaikoura, New Zealand. The median size of these groups was 14 individuals, with a minimum of 4 (2 mother-calf pairs) and a maximum of 100 (close to 50 mother-calf pairs). The distribution and behaviour patterns of nursery groups differed from other group types throughout most of the study. A total of 260 individuals were catalogued as members of nursery groups. Some adult females in nursery groups were always found together, whereas other adult females, with similarly aged calves, were never seen together in the same nursery group. Nursery groups were predominantly resting, in a formation that kept inter-animal distance to less than 1 adult body length. Nursery groups generally showed a high degree of synchrony, with almost half the groups I followed showing synchronous submergences and surfacings during most of the focal follow. Calves engaged in more high energy behaviours than non-calves in these groups. On a few occasions, nursery groups were documented engaged in foraging-like behaviours.

Nursery groups were usually encountered in depths less than 20 m. Neither large groups nor mating groups had a preference for either deep or shallow waters; however, adult non-mating groups were encountered more often in depths greater than 20 m.

The seasonality of nursery groups coincided with the time of year when male testes sizes were largest (Cipriano, 1992) and mating behaviours were most frequent (Markowitz, 2004). This suggests that females with young calves may chose to leave the large groups and spend their time in the shallows in order to avoid unwanted sexual or other types of agonistic interactions with conspecifics, especially during the “mating season”, but throughout summer and fall as well.

The seasonality of nursery groups and their preference for shallow water are also likely strategies mothers use to protect young from predators. I saw most nursery groups

during the summer months, when killer whale researcher, Ingrid Visser, has recorded the highest number of occurrences of killer whales off Kaikoura. When killer whales and sharks were encountered during my field season, they were in deeper waters on all but 1 occasion. This too suggests that the shallower waters are a refuge for females and their young.

Distribution data did not show nursery groups preferring an area with less boat traffic as was predicted. Instead, the shallow waters had many more boats, with the majority of these being private recreational boats. These were primarily recreational fishermen, using cray pots, nets, or lines to catch shallow water fish and crayfish. I cannot say, therefore, that nursery groups are gaining protection from boats and associated fishing gear when in the shallow waters. Rather, their preference for these shallow waters puts them at a higher risk for encounters with boat motors and recreational fishing gear.

The interactions with boats and fishing gear in the shallows are also of concern to other species of marine mammals off Kaikoura. There are four separate populations of Hector's dolphins (*Cephalorhynchus hectorii*), found only in New Zealand, that are under considerable threat from entanglement in fishing gear (Slooten et al., 2006). During the course of my study, 72 small groups of Hector's dolphins were recorded during surveys for dusky dolphin nursery groups. All of these were in depths less than 20 m. On 4 occasions, dusky dolphin nursery groups were joined by Hector's dolphin mother-calf pairs. By reducing fishing in the shallows, we may be helping to protect not only young dusky dolphins, but Hector's dolphins as well. Over the past 10 years, a total of 185 entangled New Zealand fur seals in the Kaikoura area have been reported to the Department of Conservation (Boren et al., 2006). Green trawl netting was responsible for 68 of these, and other net types were responsible for 28. Other materials used in fishing practices (rope, monofilament line, twine, wire, and fish hooks) were responsible for another 14. Clearly, fishing practices in this area pose a significant risk to dusky dolphin nursery groups, Hector's dolphins, and New Zealand fur seals.

Future research that is focused on nursery groups is required if we are to further our understanding of these specialized delphinid social groups. Repeated surveys in summer and fall seasons would be extremely informative when compared to the encounter rates presented in this work. By conducting surveys of the area in years to come, we can illuminate longer term trends of the density and behaviours of dusky dolphin group types in the area. By continuing aspects of the photo-ID study, we may learn more details about the reproductive parameters of females. For example, discovering when identified females are seen with new calves may shed light on the period of time females have between births. Through re-sights of distinctly marked calves, we may learn how long dusky dolphins spend being closely associated with their mothers in nursery groups. Re-sights of individuals recorded in this work would further clarify the levels of association seen in specific subgroups. Finally, it would be useful to collect photographs of nursery groups outside of my study area to see how these individuals are distributed around other parts of New Zealand, and to possibly demonstrate that Kaikoura is unique as a habitat for such a high density of reproductive females and young calves.

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